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Kennedy/Jenks Consultants

South Tacoma Field
Superfund Site
Tacoma, WA

Surface Water and Sediment Investigation Report



K/J Project No. 916055.10
Draft Report

SURFACE WATER AND SEDIMENT INVESTIGATION REPORT

**SOUTH TACOMA FIELD
SUPERFUND SITE
REMEDIAL INVESTIGATION AND FEASIBILITY STUDY**

DRAFT REPORT

Prepared for

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SURFACE WATER AND SEDIMENT INVESTIGATION

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EXECUTIVE SUMMARY

This report describes findings of the Surface Water and Sediment Investigation conducted as part of the South Tacoma Field (STF) Remedial Investigation. The Surface Water and Sediment Investigation was performed as outlined in the Final Work Plan (ICF 1990b), which established the level of effort required by the U.S. Environmental Protection Agency (EPA) to complete the RI/FS.

PURPOSE AND INVESTIGATIVE ACTIONS

The primary purpose of the Surface Water and Sediment Investigation was to characterize the types and concentration distributions of target chemicals of concern detected in surface water and sediment samples. This investigation consisted of the following specific objectives:

- Identify the source(s) of surface water flowing onto the site
- Identify background concentrations of chemicals of concern for samples collected from nearby (offsite) surface water bodies within the South Tacoma Channel
- Identify concentrations of chemicals of concern in onsite surface water and sediment samples
- Quantify the chemical composition of surface water flowing directly onto and off the STF site
- Evaluate transport of chemicals of concern to and from the site through surface water drainage.

The following tasks were completed during the Surface Water and Sediment Investigation:

- Installed a flow monitoring meter in a storm drain (72-inch pipe) at Madison Street north of South 56th Street (south end of STF site) to measure surface water flow from the site and continuously monitored flow from April 1991 through March 1992.
- Collected 10 surface water samples from five background locations within the South Tacoma Channel; each location was sampled once in the dry season (August 1991) and once in the wet season (January 1992).
- Collected a total of 41 surface water samples and 69 sediment samples during three separate sampling events (April and August 1991, and January 1992) from 29 locations within the onsite surface water channel.
- Collected 4 biweekly surface water runoff samples from the surface water channel approximately 500 feet north of the flow monitoring location.
- Collected 11 monthly surface water runoff samples from storm drain outlet south of City of Tacoma pump station.
- Collected 10 monthly surface water runoff samples from the manhole for the South 38th Street storm drain, located 50 feet west of the onsite surface water channel. The manhole was sampled because the outlet for South 38th Street storm drain was submerged (i.e., not accessible).
- Collected 11 storm event surface water samples from each of the two monthly runoff sampling locations (for a total of 22 runoff samples) and 1 storm event surface water sample from the runoff location.

Background, onsite, and runoff surface water samples collected during this investigation were analyzed for routine inorganics, ancillary inorganics (boron and cyanide), PAHs, VOCs, semivolatile organic compounds, pesticides and polychlorinated biphenyls (PCBs), and fecal bacteria. Runon surface water samples collected during this investigation were analyzed for routine inorganics, boron, PAHs, and fecal bacteria. Onsite sediment samples collected during this investigation were analyzed for routine inorganics, boron, cyanide, moisture content, PAHs, VOCs, semivolatile compounds, pesticides and PCBs, grain size distribution (dry and wet seasons only), and total organic matter (wet season only).

HYDROLOGIC CONDITIONS

Surface water from two upgradient sub-basins discharges onto the northwest portion of the STF site. Appreciable amounts of other surface water runon from offsite into the onsite surface water channel were not directly observed during this investigation. The surface water channel runs from north to south along the western boundary of the STF site. The channel comprises two areas with permanent standing water, including an area adjacent to a storm drain outfall (Location 2501) and a remnant of a former swamp. The channel runs through three culverts under established roads on the STF site as it continues from north to south. The channel eventually turns east then continues south again parallel to Madison Street where the channel crosses the southern site boundary. The channel continues offsite along Madison Street to approximately 150 feet north of South 56th Street, at which point the open channel enters a 72-inch storm drain. Surface water from STF, combined with other sources of surface water, discharges to Flett Creek approximately 1.4 miles south of the site. Approximately 3 miles farther downstream, Flett Creek discharges into Chambers Creek and eventually the Puget Sound.

Surface water does not run off of the site continuously through the channel. During periods of heavy or extended precipitation (i.e., storms of approximately 1 week in duration consisting of 2 or more inches of precipitation), the channel would fill and flow offsite. Only four offsite flow events were observed from April 1991 through March 1992.

INORGANIC ANALYTICAL RESULTS

Inorganic chemicals were detected consistently in all surface water (background, runoff, onsite, and runoff) and sediment samples collected during this investigation. The following EPA acute freshwater quality criteria (AFWQC) were exceeded in surface water samples collected during this investigation:

- Aluminum
- Cadmium (runoff and onsite only)
- Copper
- Lead (runoff and onsite only)
- Silver (onsite only)
- Zinc.

The inorganic chemicals detected in runoff stormwater samples were generally detected at higher concentrations than those detected in monthly runoff samples with the exception of major cations (calcium, magnesium, potassium, and sodium). These major cations were detected at higher concentrations in the monthly surface water runoff samples than in the stormwater runoff samples.

The metals in the onsite surface water samples were generally detected at higher concentrations in the vicinity of and directly downstream from the storm drain outfalls in the channel than in samples collected throughout the remainder of the downstream channel.

Inorganic chemicals in onsite sediment were generally detected at lower concentrations near the storm drain outfalls than in the more heavily vegetated downstream portion of the channel.

ORGANIC ANALYTICAL RESULTS

Several organic compounds were detected consistently in surface water and sediment samples collected during this investigation. PAHs were detected in background surface water, runoff surface water, onsite surface water and sediment, and runoff surface water. PAHs were detected at higher concentrations in dry season background samples than wet season samples. Detected PAH concentrations in surface water runoff were usually less than 1 $\mu\text{g/L}$. PAHs were detected more frequently and generally at higher concentrations in stormwater runoff samples than in monthly runoff samples. PAH concentrations in onsite surface water were generally higher in wet season samples than in dry season samples. Maximum PAH concentrations in onsite samples were similar to the range of maximum PAH concentrations in runoff samples. PAHs were detected less frequently in runoff than runoff, but runoff concentrations were generally similar to the runoff concentrations (generally less than 0.2 $\mu\text{g/L}$). PAH concentrations of up to 130 mg/kg were detected in onsite sediment with higher concentrations detected in the northern section of the channel.

Only trace concentrations (i.e., less than 10 $\mu\text{g/L}$) of a few VOCs were detected in surface water and sediment samples collected during this investigation. Acetone (background only), chloroform, toluene (onsite only), and methylene chloride (onsite

only) were detected in surface water samples. Only relatively low concentrations of VOCs (i.e., less than 1 mg/kg) were generally detected in sediment samples. A maximum VOC concentration of 6,400 $\mu\text{g/kg}$ of toluene was detected in one sediment sample.

Non-PAH semivolatile compounds were detected in some surface water and sediment samples. Bis(2-ethylhexyl)phthalate, a ubiquitous chemical in the environment, was detected in many of the surface water samples (i.e. background, onsite, and runoff) and sediment samples. Other chemicals detected in surface water were 4-methylphenol and pentachlorophenol, onsite and runoff, respectively. Nine non-PAH semivolatile compounds were detected in sediment at concentrations up to 160 mg/kg.

Pesticides and PCBs were not detected in surface water samples collected during this investigation. However, PCBs were detected at concentrations up to 4 mg/kg in onsite sediment samples in the northern section of the channel during the dry and wet seasons.

FECAL BACTERIA RESULTS

Fecal bacteria concentrations in background, runoff, onsite, and runoff surface water samples generally exceeded freshwater quality criteria. The ranges of all surface water fecal bacteria concentrations (i.e., background, runoff, onsite, and runoff) were similar.

RUNON AND RUNOFF WATER VOLUMES AND LOADINGS

The estimated stormwater volume flowing onto the STF site through the storm drain outfalls was approximately 100 million gallons for the 1-year investigation

runon

period (April 1991 through March 1992). The volume of surface water runoff was estimated to be 15.1 million gallons for the investigation period.

runoff

The estimated volume of surface water discharged from the STF site was substantially less than the estimated volume of surface water entering the STF site during this investigation. Hence, the majority of surface water flowing onsite was not flowing through and off the site. Much of the surface water runoff is apparently dissipated onsite due to evaporation, transpiration, and infiltration through the soil to recharge the upper aquifer beneath the site.

The estimated mass loadings of inorganics in the surface water runoff to the site were greater by several orders of magnitude than estimated inorganic loadings in runoff from the site.

CONCLUSIONS

The following conclusions have been developed based on the findings of this investigation.

Background

- Background surface water quality shows effects of urban surface water runoff contamination due to anthropogenic sources. Eleven inorganic chemicals [metals (i.e., aluminum, barium, copper, iron, lead, and zinc) and major alkali and alkaline earth metal cations (calcium, magnesium, manganese, potassium, and sodium)] were detected consistently in background surface water samples. Three metals (aluminum, copper, and zinc) exceeded AFWQC at least once in the background samples. PAHs were detected at background locations with higher concentrations detected during the dry

season. Two VOCs (acetone and chloroform) were detected during the dry season background sampling event. One non-PAH semivolatile compound [bis(2-ethylhexyl)phthalate] was detected. No PCB or pesticides were detected in any of the background samples.

Runon

- Surface water from two upgradient sub-basins discharge onto the northwest portion of the STF site. Other appreciable surface water runon from offsite into the onsite surface water channel was not directly observed during this investigation. Runon flows from the two storm drain outfalls appears to constitute the major source of onsite surface water. Other possible sources of water entering the site are precipitation, sheet runoff from the offsite hillside on the western boundary of the channel, or groundwater discharge into the channel.
- The surface water runon discharging onto the site through the two storm drain outfall exhibited degraded quality characteristic of urban runoff. Concentrations of metals, PAHs, and fecal bacteria detected in the runon samples were generally equal to or higher than those detected in onsite surface water, and appear to be significantly elevated as a result of offsite human activities.
- Major cation concentrations detected in runon samples collected during storm events were significantly less than those detected in monthly (low flow) samples. This finding is consistent with the expected chemical composition of stormwater runoff that has had a short contact time with earth materials as compared to non-storm event flows that may contain groundwater seepage or other waters with longer earth material contact times. Conversely, concentrations of metals and PAHs were generally

higher in stormwater runoff samples than in monthly samples suggesting that these contaminants are mobilized and transported from the surrounding urban environment during storm events following their surface accumulation during drier periods. Sources of PAHs in the runoff surface water are ubiquitous in urban environments. Some of these sources include petroleum products such as gasoline, tars and heavy oils, and products of combustion processes such as those produced by internal combustion engines.

Onsite

- The onsite surface water system is relatively complex with respect to the potential geochemical processes that affect surface water quality. Possible sources of chemicals potentially affecting onsite surface water quality may be runoff and contaminated sediment that have deposited onsite. Therefore, principle factors affecting onsite surface water quality are 1) the chemical quality of runoff, and 2) appreciable changes in the onsite surface water environment that will influence the mobility and transport of previously deposited contaminants through processes such as dissolution and/or resuspension and deposition.
- Sediment containing metals and PAHs may serve as a source to onsite surface water. The highest concentrations of metals and PAHs appear to be present in the upstream reaches (Reaches A and B), with the highest concentrations of PAHs being present near the storm drain outfalls. Based on the runoff conditions observed during storm events and site topography, overland transport of surface soil from other areas of the STF site does not appear to be a significant mechanism for migration of metals and PAHs into the surface water channel. Accordingly, the possible sources of metals and PAHs in onsite surface water sediment may be 1) historical deposition

of metal-bearing materials into the channel by either direct discharge or human activities resulting in enhancing erosion of such materials, 2) deposition of contaminants contained in runoff of degraded quality, or 3) deposition of airborne contaminants. Evaluation of the graphs depicting metals and PAH concentration distributions along the onsite surface water channel (showing dry weight and normalized concentrations) support the conclusion that contamination of onsite sediment is at least partially attributable to deposition of contaminants carried onsite by runoff discharged from the storm drain outfalls. This conclusion is supported by relatively high concentrations detected in sediment in Reaches A and B. In addition, the observed series of "peak" concentration points along the channel, the amplitude of which progressively decrease with distance downstream from the outfalls, are consistent with resuspension and redeposition phenomena as adsorbed metals and PAHs are progressively transported downstream by years of storm events. Such a contaminant distribution is consistent with the expected patterns of initial introduction of contaminants into the onsite surface water channel by stormwater drain discharges followed by contaminant attenuation as it moves through wider reaches and vegetated areas farther downstream.

- Higher metal and PAH concentrations were detected in onsite surface water samples collected during the dry season than in samples collected during the wet season. This finding is consistent with the concentrations of contaminants observed in stagnant surface water bodies subjected to net evaporative conditions.
- Metals and PAHs in runoff are probably the source for much of the chemical loading to the surface water channel in Reach A. The lower concentrations detected in surface water in the north ponded area (Location 2530) are typical of a relative quiescent pool where suspended solids have an opportunity to settle out of solution. Chemicals that were generally

detected at higher concentrations at the boundary of Reaches A and B may be attributable to an unidentified localized source such as a coated metal conduit located in the surface water channel. Surface water metal concentrations were generally relatively uniform in Reach C. For some chemicals (e.g., arsenic, barium, calcium), concentrations increased slightly at the southern end of Reach C. It appears that the road at this location may act as a hydraulic barrier to create a pool for suspended metals to settle.

buried debris?

Runoff

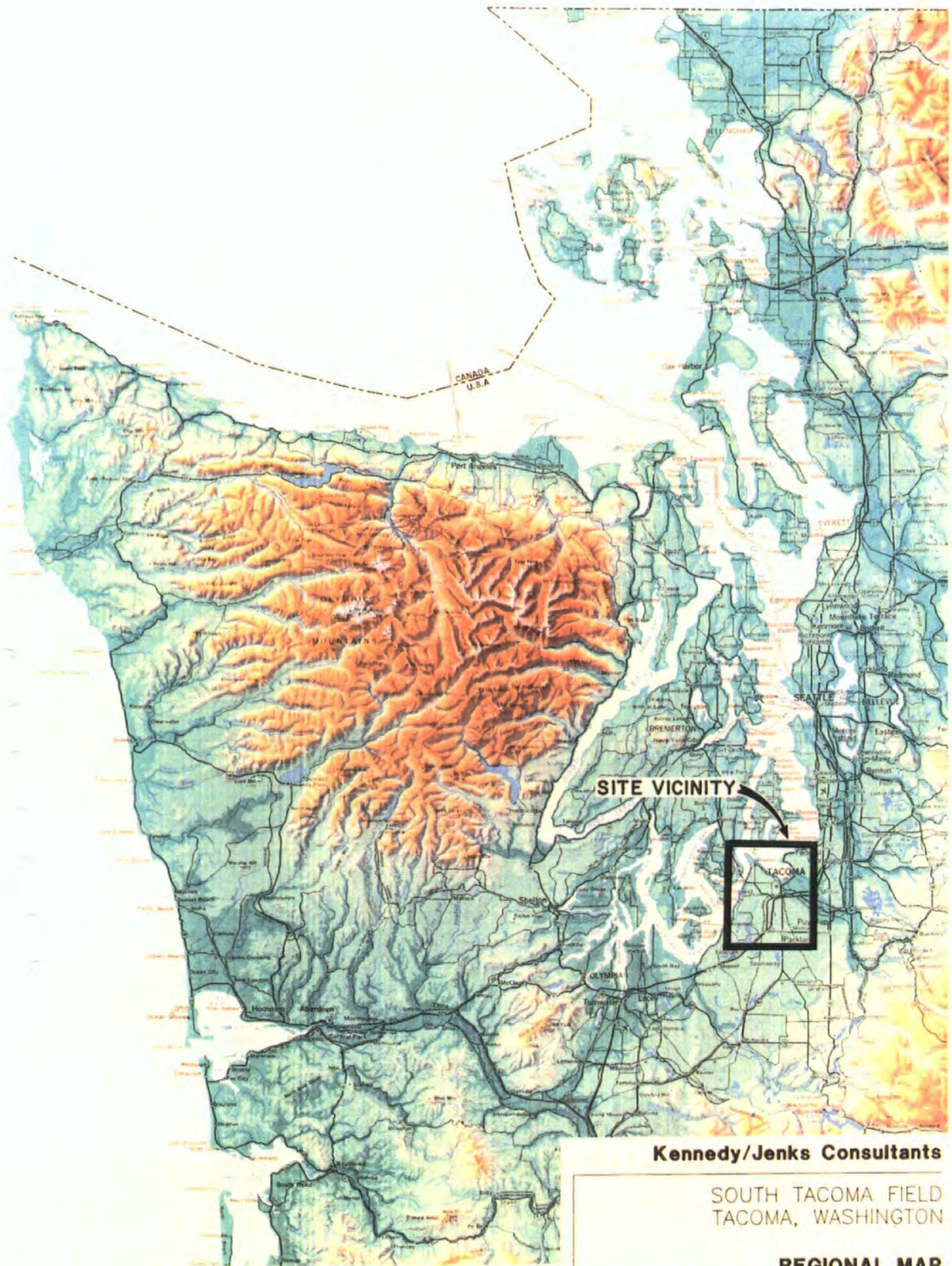
- Surface water was only observed flowing from the site during periods of heavy and/or prolonged precipitation. Based on these observations and the water balance calculations made as part of this investigation, it is reasonable to conclude that the onsite surface water channel serves as a recharge zone for the shallow aquifer in the area.
- The quality of runoff from the site was consistent with or better than runoff quality throughout the investigation, suggesting that the overall function of the onsite surface water channel is one of settling, absorbing, and otherwise retaining much of the contaminant load discharged to it from offsite, upstream sources.
- Mass loading estimations (made as part of the analysis of data gathered during this investigation) indicate that a significant quantity of the metals and PAHs discharged from offsite sources into the onsite surface water channel are retained onsite.

1.0 INTRODUCTION

This report describes findings associated with the Surface Water and Sediment Investigation conducted as part of the South Tacoma Field (STF) Remedial Investigation. The STF site, located in Tacoma, Washington, is a former industrial property approximately 300 acres in size. The site is in western Washington State (Figure G-1) in the southwestern section of the City of Tacoma (Figure G-2). Currently, the STF site is largely vacant with some remnant structures and recently constructed industrial buildings.

On 23 November 1981, the U.S. Environmental Protection Agency (EPA) published an "interim priority list" of 115 top priority hazardous waste sites targeted for action under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). The STF site was listed on the initial National Priorities List (NPL) as a portion of the Commencement Bay-South Tacoma Channel site. On 30 December 1982, EPA proposed modifications to the NPL. The list increased to 418 sites and the Commencement Bay-South Tacoma Channel site was divided into four separate sites: the Deepwater, the Nearshore, the Tideflats Industrial, and the South Tacoma Channel. On 8 September 1983 (48 FR 40658), the South Tacoma Channel site was further divided into separate operable units (e.g., STF, Tacoma Well 12-A, Tacoma Landfill) with unique NPL site numbers (Bennett, D., 3 January 1992, personal communication).

On 12 October 1990, EPA and the potentially responsible parties (PRPs) signed an Administrative Order on Consent (Consent Order) for the STF site. The Consent Order, among other requirements, directed that a remedial investigation be conducted to determine the nature and extent of environmental contamination by hazardous substances at the STF site.



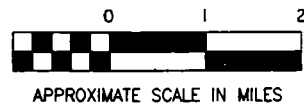
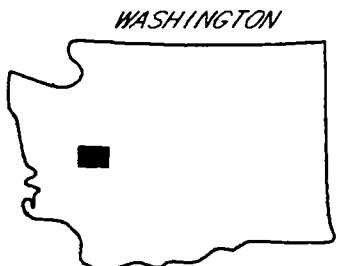
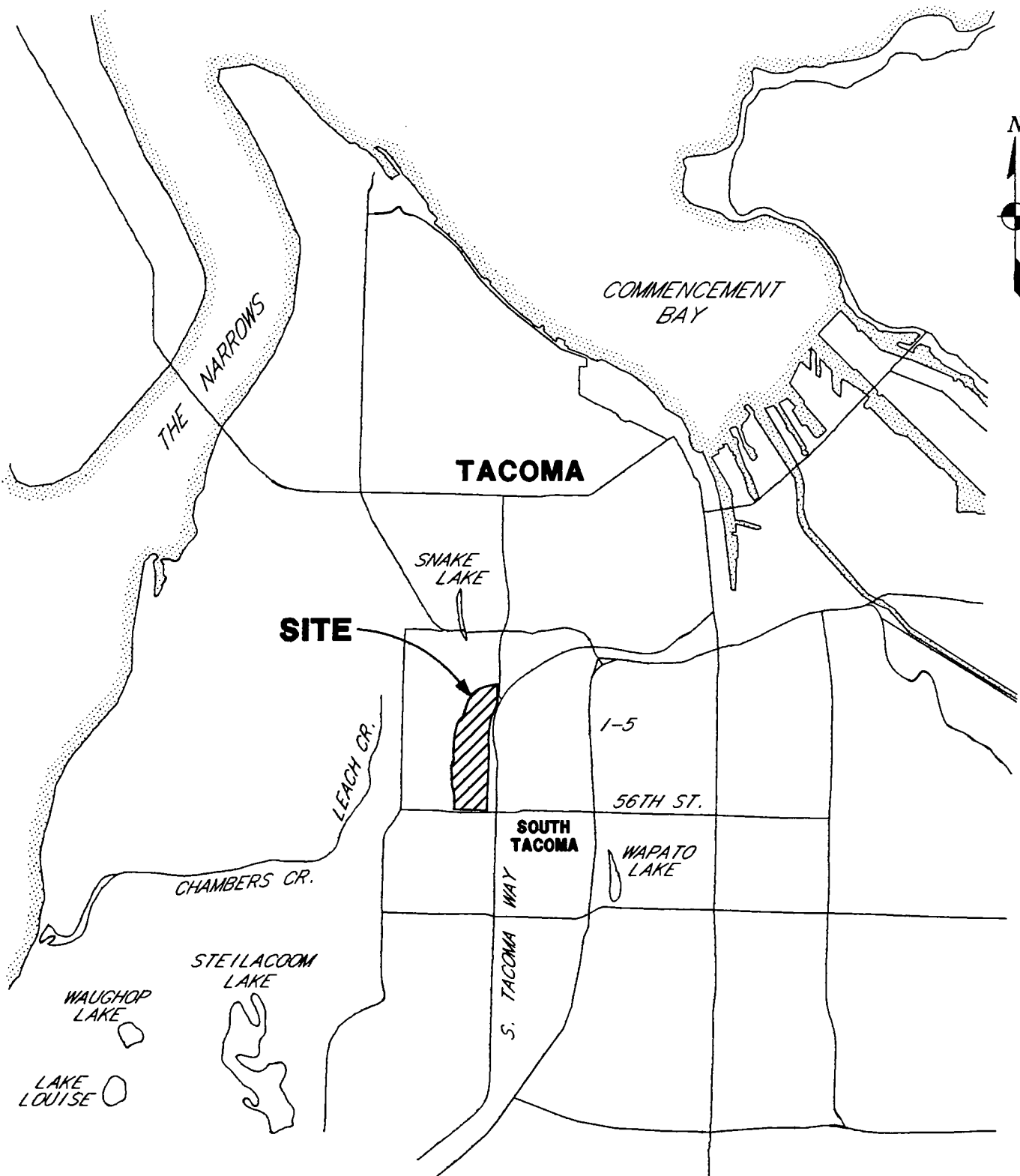
Kennedy/Jenks Consultants

SOUTH TACOMA FIELD
TACOMA, WASHINGTON

REGIONAL MAP

916055.02/P1SK092

FIGURE G-1



Kennedy/Jenks Consultants

SOUTH TACOMA FIELD
TACOMA, WA

SITE LOCATION MAP

916055.10/P2SK058

FIGURE G-2

The Consent Order cites the Final Work Plan, which establishes the level of effort required by EPA to complete a Remedial Investigation/Feasibility Study (RI/FS) at the STF site. The Final Work Plan was prepared for EPA by ICF Technology, Inc. (ICF 1990b). Kennedy/Jenks Consultants was retained by the PRPs to conduct the RI/FS in accordance with the Final Work Plan, Revision 1, dated September 1990 (ICF 1990b).

The RI is composed of discrete investigations of potential contamination associated with several media, including surface soil, subsurface soil, groundwater, surface water and sediment, and blackberries. A soil gas survey, geophysical survey, wetland delineation and endangered plant species survey, and air modeling are also discrete components of the STF RI. Results of each of these investigations will be presented separately in draft and final reports and then synthesized for the RI report. This draft report presents the findings of the STF Surface Water and Sediment Investigation.

1.1 PURPOSE OF INVESTIGATION

The primary purpose of the Surface Water and Sediment Investigation was to characterize the types and concentration distributions of target chemicals of concern detected in surface water and sediment samples. This investigation consisted of the following specific objectives:

- Identify the source(s) of surface water flowing onto the site
- Identify background concentrations of chemicals of concern for samples collected from nearby (offsite) surface water bodies within the South Tacoma Channel

- Identify concentrations of chemicals of concern in onsite surface water and sediment samples
- Quantify the chemical composition of surface water flowing directly onto and off the STF site
- Evaluate transport of chemicals of concern to and from the site through surface water drainage.

The Surface Water and Sediment Investigation consisted of the following sampling events:

- Background surface water sampling at five offsite locations during dry and wet seasons
- Onsite surface water and sediment sampling in the surface water channel during the dry and wet seasons and a transitional season
- Biweekly surface water sampling at the one runoff location
- Monthly surface water sampling at the two runoff locations
- Storm event sampling at the biweekly/runoff location and at the two monthly/runoff locations.

Analytical parameters for surface water and sediment samples [including quality assurance/quality control (QA/QC) samples] collected during each of these sampling events are detailed in the STF Field Sampling and Analysis Plan (FSAP), STF Quality

Assurance Project Plan (QAPjP), and STF Wetlands Investigation FSAP Amendment (Kennedy/Jenks/Chilton 1991b,c,e, respectively).

The following tasks were completed during the Surface Water and Sediment Investigation:

- Installed flow monitoring meter in a storm drain (72-inch pipe) at Madison Street north of South 56th Street (south end of STF site) to measure surface water flow from site; continuously monitored flow from April 1991 through March 1992.
- Collected 10 surface water samples from five background locations within the South Tacoma Channel; each location was sampled once in the dry season (August 1991) and once in the wet season (January 1992).
- Collected a total of 41 surface water samples and 69 sediment samples during three separate sampling events (April and August 1991, and January 1992) from 29 locations within the onsite surface water channel.
- Collected 4 biweekly surface water runoff samples from the surface water channel approximately 500 feet north of the flow monitoring location.
- Collected 11 monthly surface water runoff samples from storm drain outlet south of City of Tacoma pump station.
- Collected 10 monthly surface water runoff samples from the manhole for the South 38th Street storm drain, located 50 feet west of the onsite surface water channel. The manhole was sampled because the outlet for South 38th Street storm drain was submerged (i.e., not accessible).

- Collected 11 storm event surface water samples from each of the two monthly/runon locations (for a total of 22 runon samples) and 1 storm event surface water sample from the runoff location.

1.2 REPORT ORGANIZATION

This report has been prepared in accordance with the EPA's Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA (EPA 1988a).

The remaining sections of this report are summarized below:

- Section 1.0 concludes with a summary of the site background and current land use.
- Section 2.0 presents the hydrologic characterization of the STF site, including a discussion of site geology and soil, climate, surface water hydrology, and groundwater hydrology.
- Section 3.0 summarizes investigative methods used during this investigation, including an overview of field activities, a description of the types and locations of samples collected, discussions of runon mass loading estimations and runoff mass loading calculations, and a summary of analytical parameters. In addition, a discussion of continuous flow monitoring for offsite flow from the STF site is provided in Section 3.0.
- Section 4.0 summarizes the QA/QC program for field and laboratory data, including a discussion of the data validation process.
- Section 5.0 presents the investigative results (analytical data) for the surface water and sediment samples collected for this investigation.

- Section 6.0 presents the findings and conclusions based on results reported in Section 5.0.
- Section 7.0 includes references for documents cited and used in the preparation of this report.

In addition, the following appendices are bound at the end of this Draft Surface Water and Sediment Investigation Report:

- Appendix SW-A -- Monthly Precipitation Data
- Appendix SW-B -- Analyte Concentrations for Surface Water Runon
- Appendix SW-C -- Mass Loading Estimations for Surface Water Runon
- Appendix SW-D -- Summary Tables for Inorganic and Organic Analytes Detected During Onsite Seasonal Sampling Events
- Appendix SW-E -- Mass Loading Calculations for Surface Water Runoff
- Appendix SW-F -- Analytical Results for Grain Size Distribution and Total Organic Matter for Sediment Samples.

The Surface Water and Sediment Investigation Data Appendix (Data Appendix; Kennedy/Jenks Consultants 1992c) contains the analytical results, including the data validation reports for this investigation and is bound as a separate document.

1.3 SITE BACKGROUND

This section presents a brief site description and a discussion of historical activities at the STF site. More detailed information is provided in the Site Background Summary (ICF 1990a) and in the Final Work Plan (ICF 1990b).

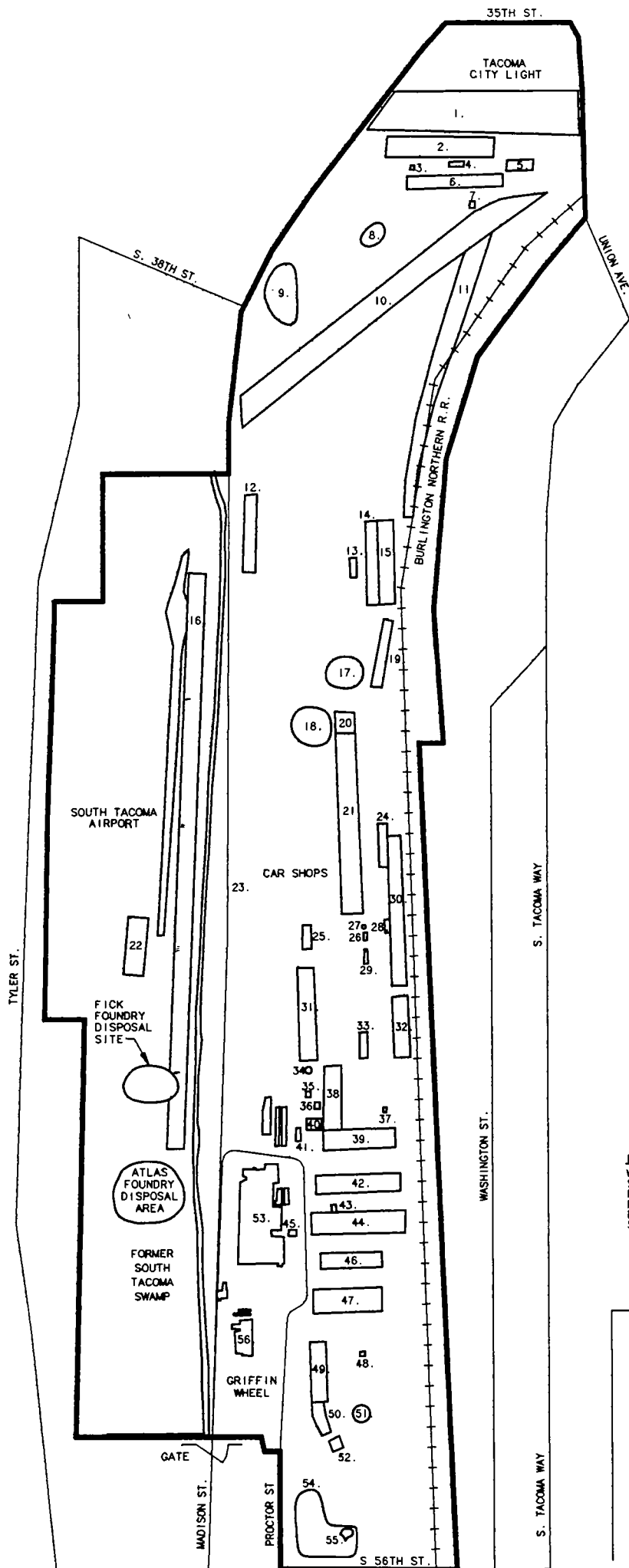
1.3.1 Site Description

The STF site is located on the floor of a topographic lowland area referred to as the South Tacoma Channel, which is as much as 150 feet lower than the surrounding uplands. The site, once covered with industrial structures, is now mostly open fields of grass with a few commercial facilities. Surface water is present in the western portion of the site, but no creeks, streams, or rivers currently pass through the site.

1.3.2 Site History

This discussion of historical activities at the STF site is based on material contained in the Site Background Summary Report (ICF 1990a). A more complete description of STF site history is available in the Site Background Summary Report (ICF 1990a), along with references to other documents that provide additional information on historical site use.

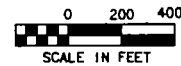
The STF site has been used for a variety of industrial purposes for approximately 100 years. Locations where various activities have taken place at the site are shown in Figure SW-1. Areas where significant historical activities occurred are briefly discussed in the following paragraphs.



LEGEND

STF-NPL SITE BOUNDARY

1. TCL YARD AREA
2. GANTRY CRANE AREA
3. FUEL TANK
4. SHED
5. LANTERN SHED
6. STOREHOUSE, BELTHOUSE
ROLLING MILL, STORAGE BLDG
7. FUEL CELLAR
8. BURN PIT
9. TRASH DUMP
10. STORAGE YARD
11. RUBBISH TRACK CORRIDOR
12. CONCRETE CASTING PLANT
13. SANDBLAST SHED
14. BLACKSMITH SHOP
15. CONCRETE FLOOR
16. LANDING STRIP
17. TRASH BURNING AREA
18. TRASH PIT (PAINT SHOP)
19. CAR CASTINGS PLATFORM
20. PAINT SHOP
21. CAR SHOP
22. AIRPORT BLDG
23. MADISON STREET
24. OPEN SHED
25. DRY KILN
26. WASTE SOAKING VAT
27. UST (OIL)
28. PAINT SHOP
29. PAINT HOUSE
30. FREIGHT REPAIR SHED
31. FINISHED LUMBER SHED
32. WHEEL SHOP
33. GENERATOR HOUSE
34. UST (OIL)
35. PUMPS
36. DIP TANK
37. DROP PIT
38. WOODWORKING SHOP
39. COACH SHOP
40. BOILER HOUSE
41. OIL TANKS
42. PAINT SHOP
43. BRASS
44. MACHINE SHOP
45. SOLVENT SHED
46. BOILER, TIN TANK, AND
COPPER SHOP
47. SOUTH MACHINE SHOP
48. TRASH BURNER
49. BLACKSMITH SHOP
50. IRON & STEEL STORAGE
51. TURNTABLE
52. COKE & COAL
53. FORMER IRON FOUNDRY
54. RAILCAR CLEANOUT AREA
55. BURIED DRUMS (REMOVED)
56. FORMER BRASS FOUNDRY SITE



BASE MAP REFERENCE

WALKER & ASSOC. 10-22-86
SURFACE DEBRIS SAMPLING PLAN
FEBRUARY 1987
FOR SITTS & HILL ENGINEERS, INC.
RETEC REMEDIATION TECHNOLOGIES, INC.
SOUTH TACOMA SWAMP

Kennedy/Jenks Consultants

SOUTH TACOMA FIELD
TACOMA, WA

**MAJOR HISTORICAL USES
OF THE STF SITE**

916055.10/P2SK033

FIGURE SW-1

The South Tacoma Car Shops area operated as a manufacturing and repair facility from 1892 until 1974. The area was used for manufacturing, repair, and maintenance of railcars, engines, boilers, and tanks.

The BNR Dismantling Yard was located in the northern portion of the Car Shops area. Cars were cleaned out and discarded materials reportedly were buried in trash pits or burned in this area.

Foundry facilities operated onsite from 1890 through 1980. An iron foundry produced iron wheels until 1957. A brass foundry produced journal bearings composed primarily of lead, tin, copper, zinc, and antimony until 1980.

The South Tacoma Airport operated from 1936 to 1973. Aircraft maintenance and refueling operations were performed at this location during those years. A lake was located beyond the south end of the former runway and, in the late 1940s, was used by seaplanes.

Throughout the history of the site, a variety of filling activities have been reported. Foundry, construction, and domestic wastes reportedly were disposed of as fill material in the Former Swamp/Lakebed area (ICF 1990a). In the 1930s and 1940s, portions of the site reportedly were used as unauthorized household and commercial waste dumping areas.

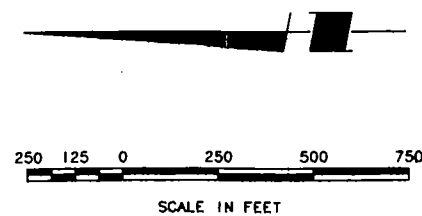
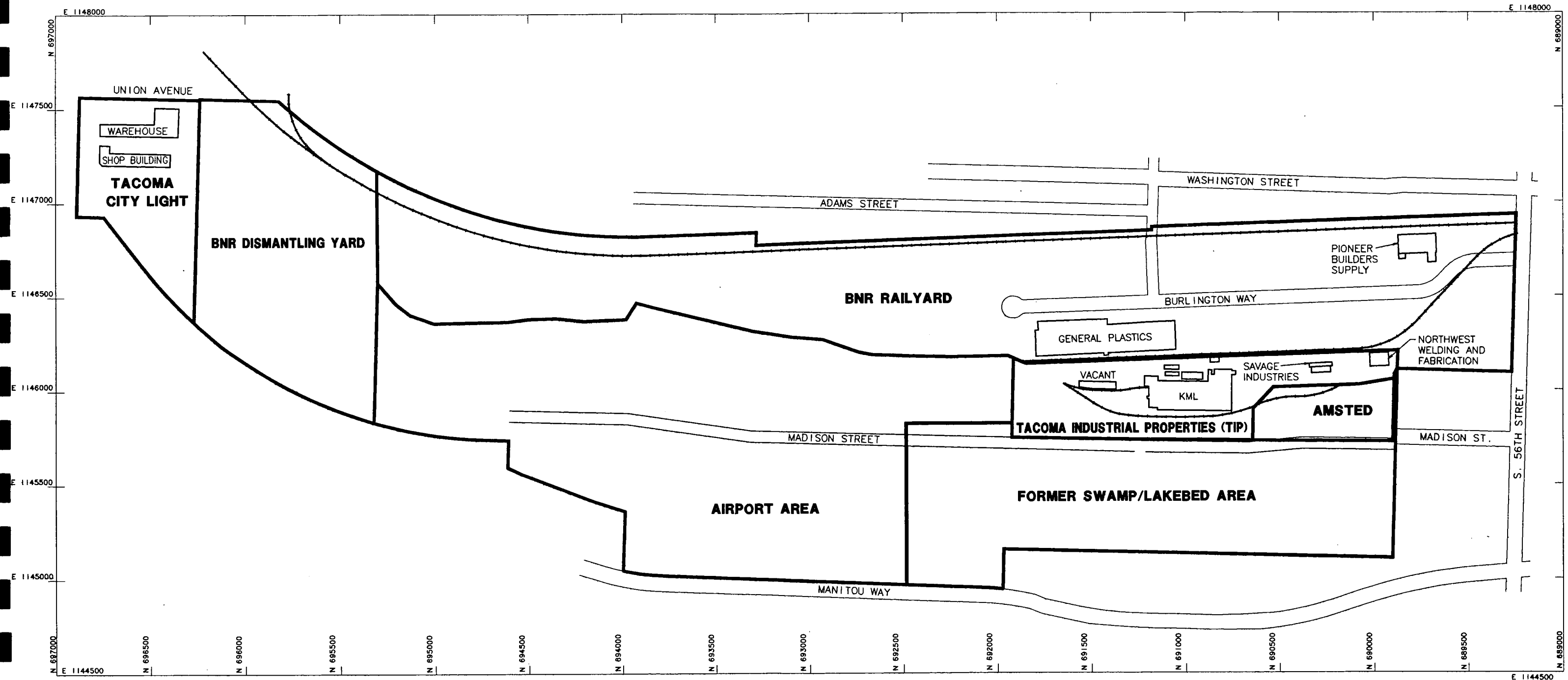
Tacoma City Light operations are located at the north end of the site. Repair, maintenance, and distribution of electric and water service equipment have occurred at the Tacoma City Light site since 1953.

1.4 CURRENT SITE USE

Much of the STF site is currently undeveloped and is covered with field grass, blackberry bushes, shrubs, and a few trees. Concrete rubble, old foundations, and trash are apparent in some areas. A portion of the STF site is used for light industrial and commercial operations. Some businesses operate from facilities previously used in association with the foundries and the railyards, while other manufacturers have constructed new facilities. Information in this section has been prepared using the Site Background Summary Report (ICF 1990a) and updated from site visits. A map of businesses currently operating on the STF site is shown in Figure SW-2.

Tacoma Industrial Properties (TIP) Management Inc. owns property in the central portion of the STF site and uses the area for a variety of industrial purposes. Three businesses operate on TIP property: KML Corporation, Savage Industries, and Northwest Welding and Fabrication (NWF). KML Corporation has operated at the old iron foundry since 1986. KML laminates films onto particle board for the construction of cabinets and interior partitions. Savage Industries has used a former BNR wood patterns and vaults building since the early 1970s to manufacture wood picture frames. NWF has operated on the southeast portion of TIP since 1986. NWF activities include repair of boats, motors, and boat trailers, as well as steel fabrication and repair.

Facilities recently constructed on STF site property include the General Plastics and Pioneer Builders Supply buildings. General Plastics manufactures high-density rigid and flexible polyurethane foams and high-density rigid polyisocyanurate foams. Pioneer Builders Supply purchased land in the southeast portion of the STF site for a warehouse and office building that were constructed in 1988. Pioneer Builders Supply operates a distribution center for asphalt and cedar roofing materials.



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SOUTH TACOMA FIELD
TACOMA, WA

**BUSINESSES CURRENTLY
OPERATING AT THE STF SITE**

916055.10/P2SK030

FIGURE SW-2

2.0 HYDROLOGIC CHARACTERIZATION

The following sections contain discussions of climate, regional and local geologic setting, surface water hydrology at and in the vicinity of the STF site, and their relationship to observed groundwater hydrology.

2.1 CLIMATE

The Tacoma region is characterized by mild temperatures, a rainy season, and cloudiness during the winter months. The U.S. Weather Bureau station at Tacoma reports an average annual precipitation of 37.06 inches. Approximately 76 percent of the annual precipitation falls during the months of October through March (Entranco Engineers 1989).

Rainfall data collected during the investigative period from April 1991 to April 1992 are summarized in Appendix SW-A. The maximum rainfall measured by McChord Air Force Base (AFB) was 4.08 inches on 9 January 1990. McChord AFB is located approximately 5 miles south of the STF site. The total amount of precipitation recorded at McChord AFB from April 1991 to April 1992 (investigative period) was 38.76 inches. Approximately 60 percent of the total precipitation fell during the months of October 1991 through February 1992.

2.2 SITE GEOLOGY AND SOIL

The general geological characteristics of the area and a description of soil associations at the STF site are described in Sections 2.2.1 and 2.2.2.

2.2.1 Geology

The STF site lies within the South Tacoma Channel (Channel), a geomorphic feature produced during the Vashon Glaciation. The Vashon Glaciation of the Puget Lowland occurred between 13,000 and 20,000 years before present. The Channel acted as a drainage course for outflow from glacial Lake Puyallup during the retreat of the Puget lobe of the glacier.

The Vashon Drift is the only geologic formation exposed at the surface in the site. The Vashon Drift consists of many members, including the Steilacoom gravel, an unnamed till unit, and the Esperance or Colvos Sand (Noble 1990). The Vashon Drift is widely exposed throughout the Puget Lowland.

The uppermost unit at the site is the Colvos Sand member of the Vashon Drift. This member consists mainly of poorly graded (well-sorted) sands containing minor amounts of gravel and silt. The Colvos Sand represents advance outwash sands and gravels that were deposited from meltwater streams along the leading edge of the glacier during its southward advance. Previous studies [Brown and Caldwell 1985; Remedial Technologies (ReTec) 1987; and ICF 1990a] indicate that the uppermost exposed unit in the Channel is the Steilacoom gravel member of the Vashon Drift. However, stratigraphic information gathered during the Phase I Soil Investigation and the well installation portion of the Groundwater Investigation (Kennedy/Jenks Consultants 1992a, 1992b, respectively) did not reveal the presence of Steilacoom gravels at the STF site.

Other units overlying the Colvos Sand were encountered locally during well installation at the site. These units included fill material and debris of anthropogenic origin, and peat and organic material near bodies of surface water.

2.2.2 Soil Associations

The U.S. Department of Agriculture Soil Conservation Survey has surveyed soils in the vicinity of the STF site (USDA 1979). Although the STF site was not included in the survey, USDA mapped soils to the west and south of the STF site. Information from the survey can provide an indication of the soil types that might be found at the site.

Soils located west of Orchard Street (approximately 0.5 miles west of the STF site) belong to the Alderwood-Everett association. This association is characterized by nearly level to rolling, moderately well-drained, and somewhat excessively drained soils that formed in glacial till and glacial outwash (USDA 1979).

The Spanaway association is predominant south of South 74th Street (approximately 1.25 miles south of the STF site). Reportedly, this association is representative of STF site soil (ICF 1990a). The Spanaway association consists primarily (67 percent) of Spanaway series soils, which are somewhat excessively drained and gravelly. Spanaway series soils formed in glacial outwash that was mixed with volcanic ash. Surface soils are characterized as gravelly sandy loam in the upper 18 inches underlain by a gravelly sand from 18 to 60 inches.

According to ICF (1990a), the original topsoil at the STF site typically consists of dark brown to black sand with silt and organic matter. The underlying layer usually consists of sandy materials and gravel. The sandy material generally conforms with the description of soils found in the Spanaway series.

A portion of the original site soils are covered by varying thicknesses of fill material (ICF 1990a). The fill material increases in depth from less than 1 foot in the eastern portion of the site to approximately 15 feet at the base of the bluff on the western boundary. However, the average fill depth is approximately 1 to 3 feet in the western portion of the site.

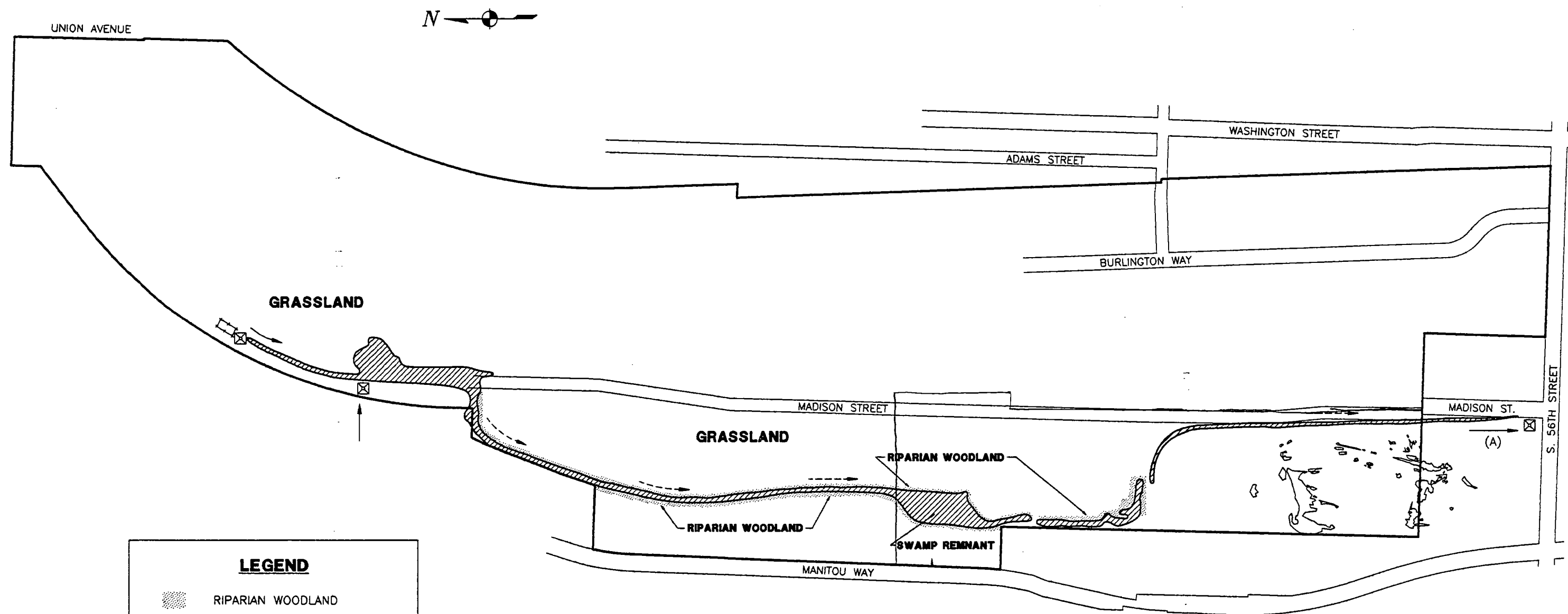
The fill materials vary, depending on the industrial operations and filling activities that occurred at particular locations and time. Fill materials include cinder, slag, scrap metal, brick, and glass. Cinder is the most common fill material, albeit large quantities of slag are apparent over extensive areas of the STF site. Local deposits of lime and sulfur are evident in the southern portion of the site, but these deposits are small in comparison to quantities of other fill materials.

2.3 SURFACE WATER HYDROLOGY

The STF site is located within the Clover/Chambers Creek surface water drainage basin. This section presents a description of the STF upgradient sub-basins within the Clover/Chambers Creek Basin and site surface water hydrology as observed during routine sampling events. Information presented herein includes observations made during the transitional season (spring), the dry season (August and September 1991), and the wet season (October through February 1992). Boundaries of jurisdictional wetlands and locations of perennial and seasonal surface water bodies are shown in Figure SW-3 and also described in the STF Wetlands Delineation and Endangered Plant Species Survey Report (Kennedy/Jenks Consultants and LSA Associates 1991).

2.3.1 Upgradient Surface Water Drainage Sub-Basins

The purpose of delineating the upgradient drainage sub-basins was to assess the surface water flow volume contributions and chemicals of concern contributed to the site by the sub-basins and potential sources within the sub-basins. The upgradient drainage sub-basins that discharge to the site are located north of STF (see Figure SW-4). The approximate boundaries of the upgradient drainage sub-basins were delineated using City of Tacoma's zoning maps and topographic maps



LEGEND

- RIPARIAN WOODLAND
- PERENNIAL WETLAND
- SEASONAL WETLAND
- STORM DRAINS (APPROXIMATE LOCATION)
- OBSERVED SURFACE WATER FLOW DIRECTION
- INFERRED SURFACE WATER FLOW DIRECTION
- (A) OBSERVED OFFSITE FLOW ON ONLY FOUR OCCASIONS

0 500
SCALE IN FEET

BASE MAP REFERENCE:
KENNEDY/JENKS CONSULTANTS AND
LSA ASSOCIATES (1991).

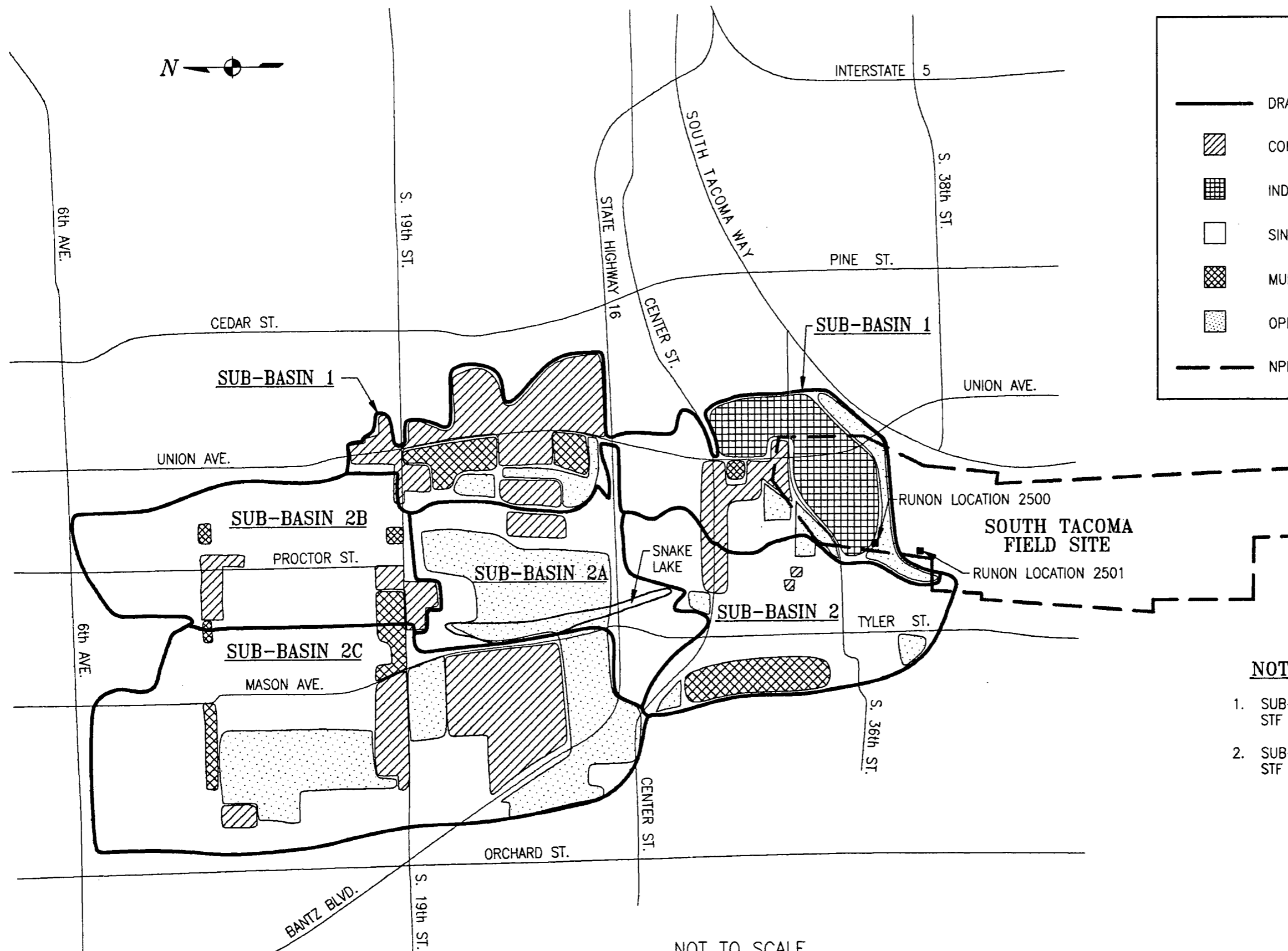
Kennedy/Jenks Consultants

SOUTH TACOMA FIELD
TACOMA, WA






BOUNDARIES OF JURISDICTIONAL WETLANDS
AND LOCATIONS OF STORMWATER DISCHARGES

916055.10/P2SK031

FIGURE SW-3



LEGEND

- DRAINAGE BASIN BOUNDARY
-  COMMERCIAL, HOSPITAL, LIGHT INDUSTRIAL
-  INDUSTRIAL FACILITIES
-  SINGLE-FAMILY RESIDENTIAL
-  MULTI-FAMILY RESIDENTIAL
-  OPEN SPACE
- - - NPL SITE BOUNDARY

NOTES:

1. SUB-BASIN 1 DISCHARGES TO THE STF SITE AT LOCATION 2500.
2. SUB-BASIN 2 DISCHARGES TO THE STF SITE AT LOCATION 2501.

Kennedy/Jenks Consultants

SOUTH TACOMA FIELD
TACOMA, WA

**DRAINAGE SUB-BASINS
AND LAND USE**

916055.10/P2SK059

FIGURE SW-4

(with storm and sanitary sewer lines depicted) [Fairchild Aerial Surveys 1950; City of Tacoma 1991] and based on visual field investigations.

Two upgradient drainage sub-basins were identified as discharging to the STF site. Surface water from Sub-basin 1 (see Figure SW-4) drains into the STF site through a 60-inch storm sewer culvert near the northwest site boundary at a location (Location 2500) approximately 100 feet south of the City of Tacoma's pump station. Surface water from Sub-basin 2 drains to the STF site through a 24-inch storm sewer culvert that enters the STF site at South 38th Street (Location 2501). Sub-basins 2A, 2B, and 2C drain directly into Snake Lake, which ultimately discharges into Sub-basin 2. However, only 51 percent of outflow from Snake Lake contributes to surface water flow into Sub-basin 2 during the months of November through March (Entranco Engineers 1989).

The upgradient drainage sub-basins are located in Township 20N, Range 2E, Sections 1, 12, and 13, and in Township 20N, Range 3E, Sections 6, 7, and 18 (Willamette Baseline and Meridian). The approximate locations of the drainage sub-basin boundaries are shown in Figure SW-4. Upgradient drainage sub-basin land use data are presented in Table SW-1. The total area of the upgradient drainage sub-basins is estimated to be approximately 1,192 acres.

2.3.1.1 Land Use. The upgradient drainage sub-basins contain a mix of land uses: single-family and multi-family residential, commercial, industrial, and open space. The following percentages approximate each type of land use in the upgradient drainage sub-basins:

- Single-family residential - 54 percent
- Multi-family residential - 5 percent

TABLE SW-1

UPGRADIENT DRAINAGE SUB-BASIN LAND USE DATA

Description	Land Use (acres)					
	Commercial	Industrial	Multi-Family	Single-Family	Open-Space	Total
Sub-basin 1	92.16	58.88	19.2	50.56	40.96	261.76
Sub-basin 2	6.40	None	23.68	124.16	10.88	165.12
Sub-basin 2A	7.04	21.12	None	60.80	65.28	154.24
Sub-basin 2B	10.88	None	5.12	159.36	None	175.36
Sub-basin 2C	72.96	18.56	11.52	247.04	85.76	435.74
Totals	189.44	98.56	59.52	641.92	202.88	1,192.32

See Figure SW-4.

- Commercial (including medical facilities and schools) - 16 percent
- Industrial - 8 percent
- Open space - 17 percent.

Major traffic arterials within the upgradient drainage sub-basins include a section of State Highway 16, Union Avenue, Center Street, South 19th Street, Proctor Street, and Stevens Street (which turns into Mason Avenue and Tyler Street). All streets and arterials contribute runoff to the upgradient drainage sub-basins.

For the purposes of this investigation, several types of facilities located in the drainage sub-basins, including medical facilities and schools, are classified as "commercial" because the percentage of impervious surface area at these facilities appears to be closest to the typical percentage for commercial areas (60-70 percent). Most of the facilities classified as commercial have parking lots of significant size. For this investigation, the following facilities in the drainage sub-basins were classified as commercial: Tacoma Central Shopping Center; Elks Lodge; Allenmore Medical Center; Fred Meyer; Bellarmine Preparatory High School, Foss High School, and other schools (athletic fields are classified as open space); Cheney Stadium; paint and auto body shop; and several small businesses in commercially zoned areas and associated parking lots.

Industrial facilities located in the drainage sub-basins include Nalley's Fine Foods, Tacoma City Light facilities, Tacoma Public Schools Building and Grounds maintenance facility, and City of Tacoma Water Department.

Open spaces within the drainage sub-basins include Snake Lake Park, Heidelberg Athletic Field, and DeLong Playground.

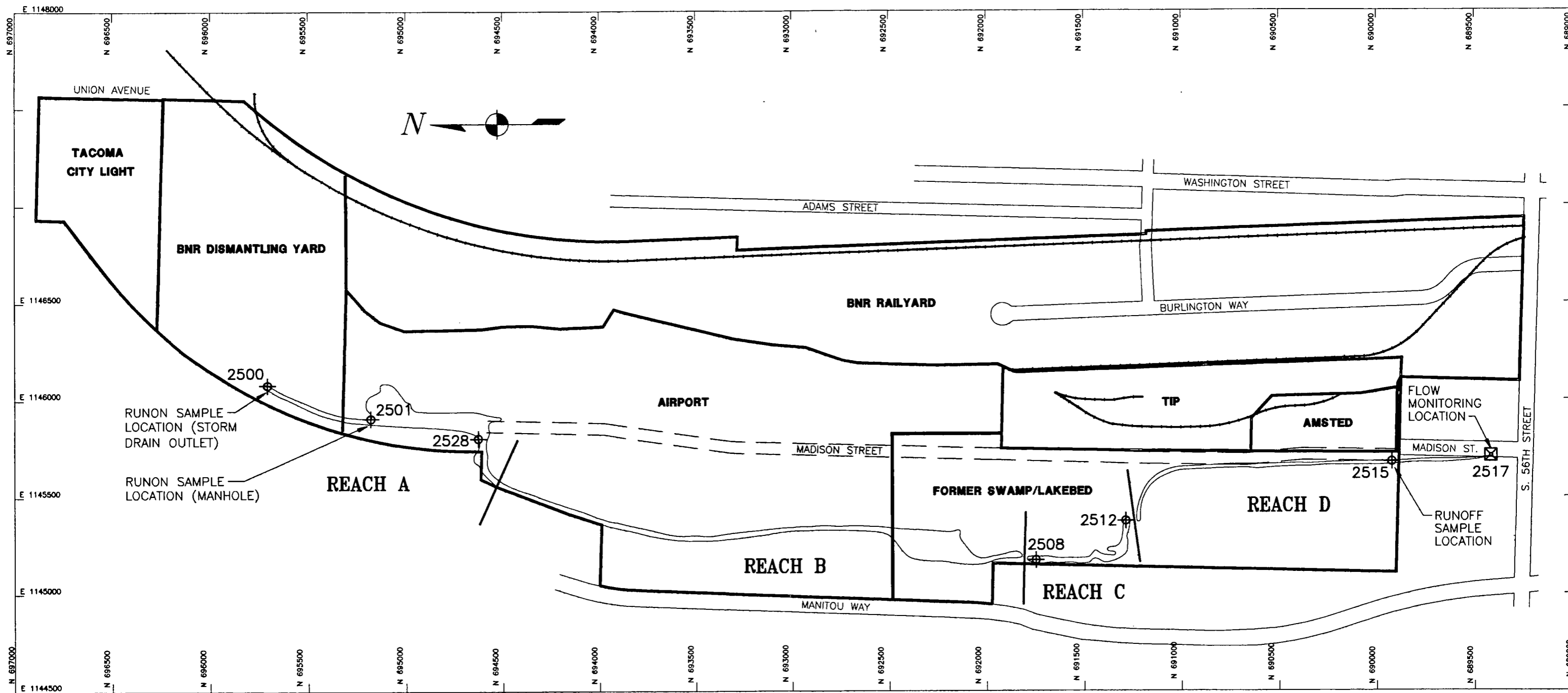
2.3.2 Onsite Surface Water

Based on the hydrologic characteristics of the onsite surface water channel as observed and noted throughout this investigation, four reaches (A, B, C, and D) were identified as shown in Figure SW-5. Reach A begins at Location 2500 and consists of the north end channel where surface water is present year-round.

Reach B includes the drainage channel along the western boundary of the Airport where surface water is usually present during the wet season. Reach C includes the north section of the Former Swamp/Lakebed where surface water is consistently present after periods of precipitation. Reach D continues along the southeast edge of the Former Swamp/Lakebed, parallel to Madison Street where surface water is present after periods of heavy precipitation. Observations of the surface water and characteristics of the four reaches are discussed below. Seasonal variations in the spatial extent and depth of surface water were observed during the biweekly monitoring events.

2.3.2.1 Reach A. The open surface water channel in Reach A is primarily situated along the western boundary of the site (see Figure SW-5). The channel begins at the northwest corner of the site where a 60-inch wide storm drain box culvert opens into an approximate 6-foot-wide open channel (Location 2500). This box culvert drains stormwater that originates from commercial and light industrial properties, which are located north of the site. This upgradient drainage sub-basin (identified as Sub-basin 1 in Figure SW-4) drains approximately 262 acres.

The other storm drain, the 24-inch diameter pipe that is parallel to 38th Street, was also observed to contribute surface water flow to the site surface water channel at Location 2501, approximately 600 feet south of the box culvert (see Figure SW-5). This pipe drains stormwater from an area of residential and light commercial properties that are located north-northwest of the site. This sub-basin is identified



LEGEND

- 2502 SURFACE WATER/SEDIMENT
SAMPLE LOCATIONS
- 2517 FLOW MONITORING
LOCATION ONLY

250 125 0 250 500 750
SCALE IN FEET

Kennedy/Jenks Consultants

SOUTH TACOMA FIELD
TACOMA, WA

REACH LOCATIONS

916055.10/P2SK034

FIGURE SW-5

as Sub-basin 2 (including Sub-basins 2A, 2B, and 2C) in Figure SW-4 and drains approximately 930 acres.

The flow of surface water onto the site from the 60-inch diameter storm sewer on the northwest part of the site is continuous throughout the year. During the dry summer and fall months (August and September), the observed flow rates onsite were typically low compared to the winter months. During storm events and the transitional season (spring), moderate to high flow rates onto the site were observed. During the dry months, little or no flow discharges were observed at the 38th Street (24-inch diameter) storm drain.

To the south, the surface water channel widens into the north swamp remnant which is east of the 38th Street storm-drain outfall. Surface water in the north swamp remnant is present throughout the year. The surface water channel continues southward from the north swamp remnant becoming a channel again at Location 2528. The channel at Location 2528 flows into a culvert under Madison Street. At that point, it appears that the culvert acts as a dam which has eventually created the swamp remnant over time. Surface water is present in Reach A up to the culvert throughout the year. In heavier storm events during any season, Reach A floods its banks to create a large pond, 4 feet deep, in the northern portion of the Airport area. During the dry summer and fall months, surface water is present at the north end of the site (Location 2500) to approximately 1,200 feet to the south.

2.3.2.2 Reach B. In Reach B, the open surface water channel runs south along the western boundary of the site in the Airport area. Although the portion of the channel in the Airport and Former Swamp/Lakebed areas is dry during the dry season, occasional storms or showers fill the channel in the north section of the Former Swamp/Lakebed area with several feet of standing water. The south swamp remnant was observed to contain surface water during the wet season and to be dry in the late dry season (August and September 1991). During the

transitional season, standing water was observed in the open channel for much of its length and in the south swamp remnant. A culvert located at Location 2508 diverts the surface water under a dirt road. At that point, the combination of the road and culvert appear to be acting as a dam, which has eventually created the south swamp remnant. Standing surface water is usually present north of the culvert.

2.3.2.3 Reach C. In Reach C, the open surface water channel continues to run south along the western boundary of the site and then turns to the east. During the winter months, water was present in the channel north of South 50th Street. During the drier periods, water was present in the channel north of South 50th Street after heavy precipitation events. The culvert and South 50th Street at Location 2512 appeared to act as a dam to back up collected surface water in the channel to the east and north of the culvert.

2.3.2.4 Reach D. The open surface water channel (south of South 50th Street) continues to run east then turns to the south to parallel Madison Street. During the transitional season, standing water was observed in the channel up to about 50 feet south of South 50th Street. Standing water was also observed in the southwest portion of the Former Swamp/Lakebed area during the transitional and dry seasons.

2.3.3 Offsite Flow

Based on observations of surface water conditions and existing subsurface conditions in the Former Swamp/Lakebed area, it appears that surface water does not flow offsite except during major rainfall events. Even during these major events, the flow observed to drain offsite may originate in the immediate area of the southern site boundary. During the dry and transitional seasons, surface water has not been observed to flow offsite and is suspected to dissipate due to

evaporation, transpiration, and infiltration through the soil and sediment to recharge the upper aquifer at the site. The surface water channel crosses the southern site boundary (at Location 2515) and continues offsite to a location parallel to Madison Street that is approximately 150 feet north of South 56th Street (Location 2517, Figure SW-5), at which point the open channel enters a 72-inch diameter storm drain. Surface water from the STF site, combined with other sources of surface water, discharges to Flett Creek approximately 1.4 miles south of the site. Approximately 3 miles farther downstream Flett Creek discharges into Chambers Creek and eventually into Puget Sound.

Flows of surface water offsite were only observed in the transitional and wet seasons during and after high-intensity storm events. Offsite flows were measured at the southern site boundary where continuous monitoring was conducted. Offsite surface water flow was observed on only four occasions during this investigation. In April 1991, offsite flow was observed during a storm event that produced 2.82 inches of rain in a 48-hour period (see Appendix SW-A). The total precipitation produced by the same storm system was 6.85 inches in 9 days, which created surface water flow offsite for a 2-week period. Surface water also flowed offsite during 2 days in late November 1991 after 6 days of rain. The third (3 February 1992) and fourth (19 February 1992) offsite flow events occurred after several weeks of rain. No offsite flow was observed in the dry months during this investigation.

2.4 GROUNDWATER HYDROLOGY

The following sections summarize the regional and local groundwater hydrologic conditions as they relate to the STF site surface water hydrology.

2.4.1 Regional Groundwater System

In general, the regional groundwater system in the uppermost unconfined aquifer (upper aquifer) is characterized by recharge in the Fircrest/Tacoma upland with shallow groundwater flow east and west to the Puyallup River Valley and to Puget Sound, respectively. The divide between east and west flow occurs in the vicinity of the South Tacoma Channel (Black & Veatch 1990). The STF site and vicinity are located within a groundwater recharge area. Groundwater is presumed to flow from the recharge areas in the central portion of the Fircrest/Tacoma upland toward the discharge areas to the west, north, northeast, and south (Black & Veatch 1987). Groundwater discharges to Puget Sound and Commencement Bay to the west and north. Groundwater flows west beneath the Tacoma Landfill and discharges to Leach Creek (Black & Veatch 1990).

The STF site is located within the Clover/Chambers Creek surface water drainage basin. The general direction of the groundwater hydraulic gradient in this basin is southeast to northwest (Brown and Caldwell 1985). This hydraulic gradient direction coincides with the hydraulic gradient direction observed in the upper aquifer at the STF site when the City of Tacoma is not pumping from the wellfield to the east of the site.

2.4.2 Local Groundwater System

Based on available potentiometric data, the STF site appears to lie within a groundwater recharge area. Based on information gathered during this investigation, precipitation and surface water from the open channel in the western portion of the site does not typically flow offsite as surface water, except during major rainfall events. Surface water is believed to dissipate by evaporation, transpiration, and infiltration downward through soil and sediment to recharge the saturated zone.

The unsaturated zone at the STF site is composed mainly of the upper portion of the Colvos Sand unit. Other local deposits comprising the unsaturated zone include fine-grained sediment and organic material in the Former Swamp/ Lakebed area and areas of anthropogenic fill material.

The upper aquifer at the STF site occurs within the Colvos Sand unit. Most of the groundwater monitoring wells at the STF site are screened in the uppermost part of the Colvos Sand in poorly graded to well graded, fine- to medium-grained sand. Where observed during the Phase I Groundwater Investigation, the lower portion of the upper aquifer consisted mainly of gravel.

The top of the upper aquifer was encountered at depths ranging from near ground surface in the Former Swamp/Lakebed area to approximately 35 feet below ground surface (BGS) in the southeastern portion of the site. However, maximum potentiometric head differences among monitoring wells during each water level monitoring event measured at the site were on the order of 6 feet. The surface housing above monitoring well CBS-8A, in a low portion of the Former Swamp/Lakebed area, was observed to be submerged under approximately 1.5 feet of surface water during the April water level monitoring event. The depth to the upper aquifer varies seasonally, by as much 10 feet over much of the site. These seasonal variations in depth to the upper aquifer are dependent on climatic conditions and pumping activity at the City of Tacoma wellfield to the east of the site.

Based on available potentiometric surface data for the upper aquifer, a natural groundwater divide appears to be located in the vicinity of the South Tacoma Channel. This divide shifts to the west toward or in the vicinity of the Tacoma Landfill when the City of Tacoma production wells are pumping (Black & Veatch 1987). The presence of this divide in the vicinity of the South Tacoma Channel is likely due in part to the absence of the poorly transmissive glacial till unit that typically overlies the Colvos Sand in the region. The more highly transmissive

Colvos Sand is exposed in the South Tacoma Channel and should promote more rapid infiltration of precipitation and surface water into the upper aquifer. Other subsurface features, such as aquifer grain size variations and aquifer thickness variations, also may have local impacts on the recharge characteristics of the aquifer.

During times when the City of Tacoma was not pumping from the wellfield to the east of the STF site (April and early May 1991), monitoring well water level data indicated the formation of a potentiometric "mound" in the upper aquifer in the southern portion of the site. A recharge mound centered in the vicinity of Amsted during the 11 April 1991 groundwater level monitoring event may be attributed to heavy precipitation that occurred in March and early April. The actual location of the center of the mound may have been to the west of the Amsted property in the area of the open channel or Former Swamp/Lakebed area.

In summary, fluctuations in the shallow aquifer potentiometric surface occur rapidly in response to precipitation events and groundwater extraction from deeper aquifers in the City of Tacoma wellfield to the east of the site. The pronounced impact of precipitation and groundwater withdrawal on observed water levels in the shallow aquifer appear to be largely due to the absence of a low permeability glacial till unit in the shallow saturated zone of the site.

3.0 FIELD ACTIVITIES AND INVESTIGATIVE METHODS

Discussions of the following field activities and investigative methods for the Surface Water and Sediment Investigation are presented in this section:

- Summary of sampling events, flow monitoring, and surveying of sample locations
- Background, runoff, onsite, and runoff sampling events and their associated sample locations
- Analytical parameters for samples collected during this investigation
- Methods used to estimate runoff mass loadings
- Runoff monitoring and methods used to calculate runoff mass loadings.

3.1 OVERVIEW OF FIELD ACTIVITIES

The Surface Water and Sediment Investigation included collection of surface water and sediment samples, installation of a continuous flow meter, and collection of survey data for sample locations. These activities are summarized herein.

3.1.1 Summary of Sampling Events

The Surface Water and Sediment Investigation consisted of background, biweekly/monthly, storm, and three seasonal sampling events. Samples were

collected from offsite and onsite locations (including the runoff locations and one runoff location) as summarized below:

- Surface water samples were collected from five background locations once during the dry season (August 1991) and once during the wet season (January 1992)
- Surface water samples were collected monthly and during storm events from two runoff locations
- Surface water samples were collected biweekly and during storm events from the runoff location
- Surface water and sediment samples were collected from specific locations within the onsite surface water channel during three separate sampling events [i.e., transitional season (April 1991), dry season (August 1991), and wet season (January 1992)].

Sample locations and the number of surface water and sediment samples collected for each sampling event are listed in Table SW-2. All surface water and sediment sampling was performed in accordance with Standard Operating Guidelines (SOGs) described in the STF FSAP and the STF Wetlands FSAP Amendment (Kennedy/Jenks/Chilton 1991b,e, respectively).

3.1.2 Installation of Flow Meter

A flow meter (Marsh-McBirney, Inc. Flowtote) was installed in a storm drain (72-inch inlet pipe) at Madison Street north of South 56th Street (south end of the STF site) to measure surface water flow from the site. This location (2517) is the

TABLE SW-2

**SUMMARY OF SAMPLE LOCATIONS, SAMPLING EVENTS, AND
NUMBER OF SAMPLES COLLECTED FOR THE STF
SURFACE WATER AND SEDIMENT INVESTIGATION**

Sample Location	Surface Water			Surface Water ^(d)			Sediment ^(d)			Background ^(e) Surface Water	
	Biweekly ^(a)	Monthly ^(b)	Storm ^(c)	Transitional Season (4/91)	Dry Season (8/91)	Wet Season (1/92)	Transitional Season (4/91)	Dry Season (8/91)	Wet Season (1/92)	Dry Season (8/91)	Wet Season (1/92)
Onsite											
2500 ^(f)		11	11								
2501		10	11		1	1		1	1		
2502					1	1		1	1		
2503					1	1		1	1		
2504					NS ^(g)			1	1		
2505					NS	1		1	NS ^(h)		
2506 ⁽ⁱ⁾				2	NS	2	1	2	1		
2507					NS	1		1	1		
2508					1	1		1	1		
2509 ⁽ⁱ⁾				2	NS	2	1	2	2		
2510					1	1		1	1		
2511 ⁽ⁱ⁾				2	NS	2	1	2	2		
2512					NS	1		1	1		
2513					NS			1	1		
2514					NS			1	1		
2515	4		1		NS			1	1		
2516 ⁽ⁱ⁾				2	NS	2	2	2	2		
2517 ^(j)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
2518					NS	1		1	1		
2519					NS	1		1	1		
2520					NS	1		1	1		
2521					NS	1		1	1		
2522					NS	NS		1	1		
2523					NS	NS		1	1		
2524					NS	NS		1	1		
2525					NS	NS		1	1		
2526					NS	NS		1	1		
2527					1	1		1	1		
2528					1	1		1	1		
2529					1	1		1	1		
2530					1	1		1	1		

TABLE SW-2

SUMMARY OF SAMPLE LOCATIONS, SAMPLING EVENTS, AND NUMBER OF SAMPLES COLLECTED FOR THE STF SURFACE WATER AND SEDIMENT INVESTIGATION

Sample Location	Surface Water			Surface Water ^(d)			Sediment ^(d)			Background ^(e) Surface Water	
	Biweekly ^(a)	Monthly ^(b)	Storm ^(c)	Transitional Season (4/91)	Dry Season (8/91)	Wet Season (1/92)	Transitional Season (4/91)	Dry Season (8/91)	Wet Season (1/92)	Dry Season (8/91)	Wet Season (1/92)
Background											
2500 ^(f)										1	1
2540										1	1
2541										1	1
2542										1	1
2543										1	1

- (a) Surface water runoff samples were scheduled to be collected biweekly from Location 2515. However, because surface water flow was seldom observed at Location 2515, only 4 samples were collected.
- (b) Surface water runoff samples were collected monthly from Locations 2500 and 2501.
- (c) Surface water runoff samples were collected during 11 separate storm events from Locations 2500 and 2501. Surface water runoff samples were scheduled to be collected during the same storm events from Location 2515. Because surface flow was seldom observed at Location 2515, only 1 stormwater runoff sample was collected.
- (d) Surface water and sediment samples were collected during three sampling events: transitional season (April 1991), dry season (August 1991), and wet season (January 1992). These samples were collected from the onsite surface water channel.
- (e) Surface water samples were collected from five background locations once during the dry season (August 1991) and once during the wet season (January 1992). Location 2500 is an onsite location that was also sampled as a background location (see footnote f).
- (f) Location 2500 is an onsite location that was also sampled as a background location. The outlet of the storm drain at Location 2500 carries surface water runoff from residential and commercial areas located north of the site.
- (g) NS - No sample collected. Surface water not present at sample location.
- (h) Surface debris prohibited collected of sediment sample at this location.
- (i) Two samples were collected in one sampling grid for Locations 2506, 2509, 2511, and 2516.
- (j) Location 2517 is an offsite location. The flow monitoring gage was installed at Location 2517. No samples were collected from this location.

only known point where surface water discharges from the STF site. Flow was monitored continuously at Location 2517 from March 1991 through March 1992.

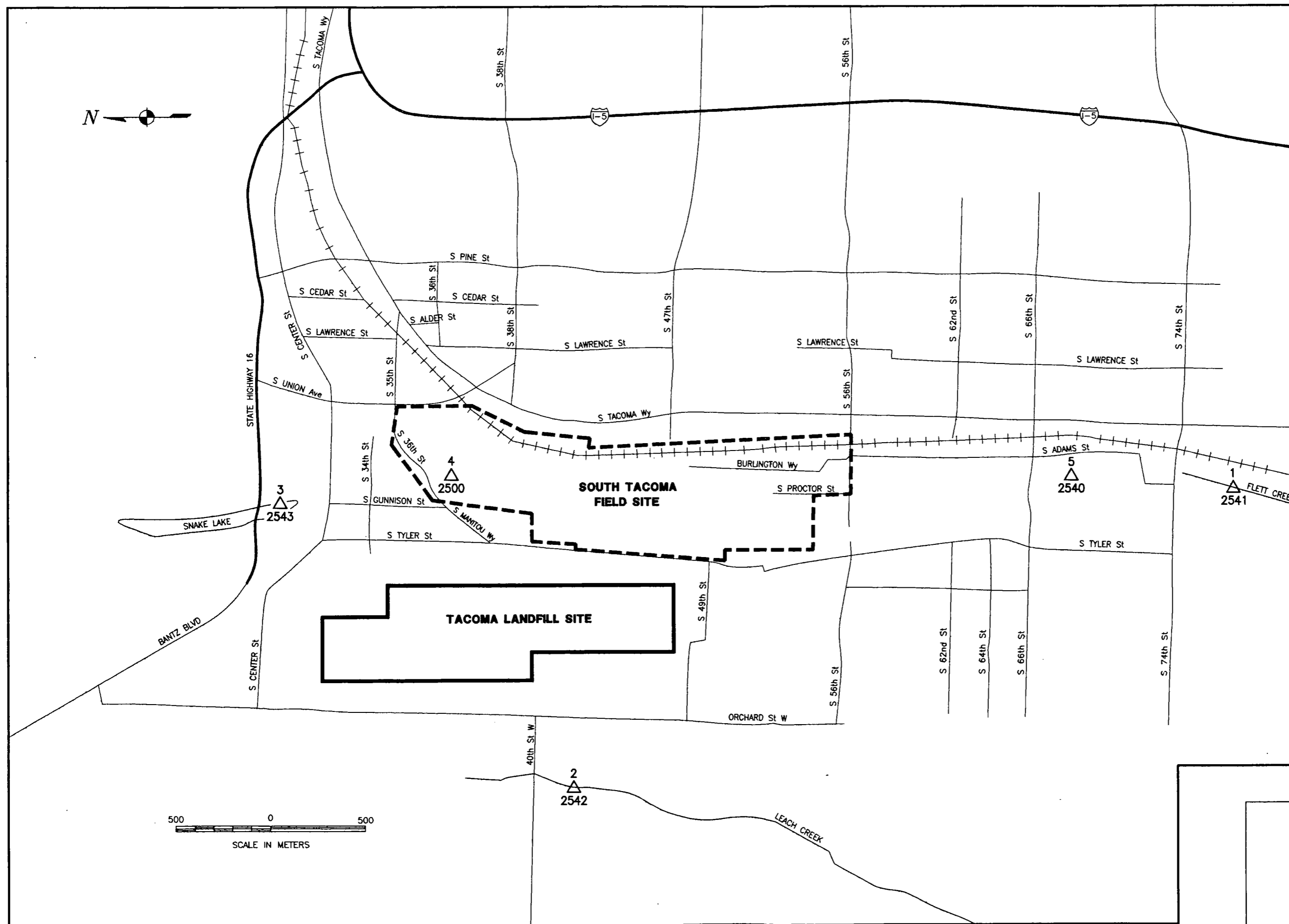
3.1.3 Survey of Sample Locations

The 30 onsite sample locations and the flow monitoring location were surveyed by PEI/Barrett Consulting Group. These locations were surveyed for horizontal (northing and easting) coordinates in reference to the City of Tacoma NAD 83 horizontal datum. Vertical elevations were surveyed in reference to the City of Tacoma NGVD 29 vertical datum. Survey location data are presented in Section 3.0 of the Data Appendix (Kennedy/Jenks Consultants 1992c).

3.2 BACKGROUND SURFACE WATER SAMPLING

The Final Work Plan (ICF 1990b) specified that background surface water samples be collected from 10 locations. However, the presence of offsite surface water in the vicinity of STF is limited and intermittent. Therefore, only five background surface water sample locations were identified for sampling (as stated in the Wetlands Investigation FSAP Amendment). The background sample locations, located within 1 mile of the STF site and within the South Tacoma Channel, are described below and shown in Figure SW-6:

1. Location 2541 - Flett Creek drainage basin south of South 74th Street and west of South Tacoma Way
2. Location 2542 - Leach Creek south of South 40th Street West and west of Orchard Street West



LEGEND

- 3
△
2543 BACKGROUND SURFACE WATER SAMPLING LOCATION
- SOUTH TACOMA FIELD SITE BOUNDARY
- TACOMA LANDFILL SITE BOUNDARY

NOTES:
1. ALL LOCATIONS ARE APPROXIMATE.

BASE MAP REFERENCE
AMERICAN DIGITAL CARTOGRAPHY
SOUTH TACOMA, WA QUAD AND
STEILACOOM, WA QUAD

Kennedy/Jenks Consultants

SOUTH TACOMA FIELD
TACOMA, WA

**BACKGROUND SURFACE WATER
SAMPLE LOCATIONS**

916055.10/P2SK032

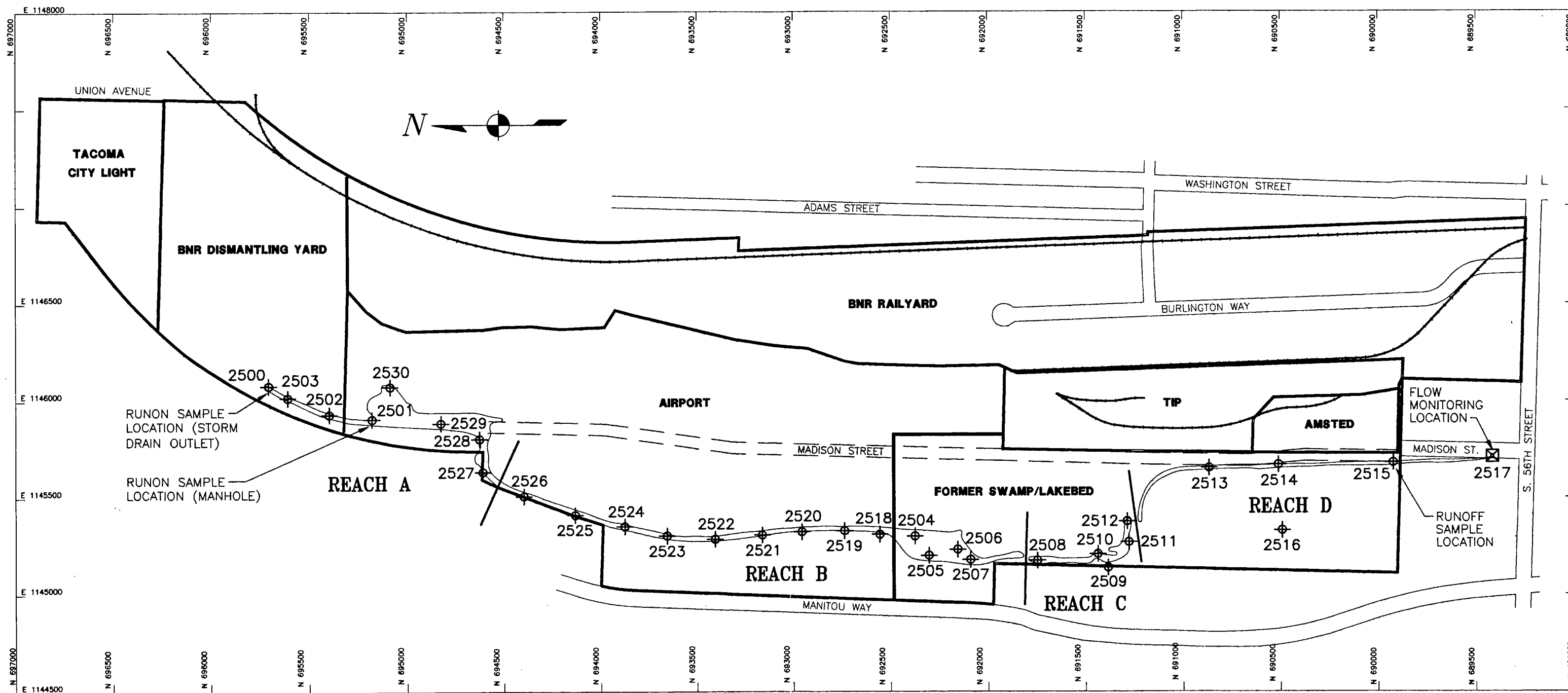
FIGURE SW-6

3. Location 2543 - Snake Lake south of State Highway 16 and west of South Union Avenue
4. Location 2500 - Outlet of storm drain (No. 1707) south of South 36th Street (this drain carries surface water runoff from residential and commercial areas located north of the site and was included to better characterize surface water runoff to STF).
5. Location 2540 - An unnamed established pond south and west of the intersection of South 66th Street and South Adams Street.

These five background locations were sampled twice, once in the dry season (August 1991) and once in the wet season (January 1992) in conjunction with the onsite surface water and sediment sampling events.

3.3 SURFACE WATER RUNON SAMPLING

Although sampling of surface water runoff was not required in the Final Work Plan (ICF 1990b), runoff sampling was performed to obtain additional data with which to quantify the chemical composition of surface water flowing onto the STF site. This additional sampling was proposed in the Wetlands Investigation FSAP Amendment and approved by EPA. Two runoff sampling locations (2500 and 2501) were identified in the Wetlands Investigation FSAP Amendment and are shown in Figure SW-7. Location 2500 is directly south of the City of Tacoma sanitary sewer pump station (northwest boundary of the STF site), where a 60-inch storm drain discharges to the open channel at the head of the STF surface water channel. Location 2501 is a manhole for the South 38th Street storm drain. The manhole, located approximately 50 feet west of the onsite surface water channel, was selected as a sample location because the outlet for this storm drain was



LEGEND

- 2502 SURFACE WATER/SEDIMENT
SAMPLE LOCATIONS
- 2517 FLOW MONITORING
LOCATION ONLY

250 125 0 250 500 750
SCALE IN FEET

NOTE:

LOCATION 2500 ALSO
CONSIDERED BACKGROUND
SAMPLE LOCATION.

Kennedy/Jenks Consultants

SOUTH TACOMA FIELD
TACOMA, WA

**ONSITE SURFACE WATER AND
SEDIMENT SAMPLE LOCATIONS**

916055.10/P1SK400

FIGURE SW-7

submerged at the point of discharge to the STF site. Sources of surface water flowing from these two drains are described in Section 2.3.1.

3.3.1 Monthly Runon Sampling

Surface water samples were collected from the two runon locations approximately every 4 weeks (i.e., every other biweekly sampling event) starting in April 1991 and continuing through March 1992. A total of 21 surface water samples were collected from the runon locations (11 at Location 2500 and 10 at Location 2501).

3.3.2 Stormwater Runon Sampling

Surface water samples were collected from the two runon locations during peak flows resulting from storm events. Surface water samples from 11 storm events were collected at both runon locations.

Each storm event sampled was characterized (i.e., duration and total inches of rainfall) using daily precipitation data obtained from McChord AFB. Daily precipitation and storm event data are provided in Appendix SW-A.

3.4 ONSITE SURFACE WATER AND SEDIMENT SAMPLING

Surface water and sediment samples were collected from the onsite surface water channel during three separate sampling events [i.e., transitional season (April 1991), dry season (August 1991), and wet season (January 1992)]. The onsite surface water and sediment sample locations are shown in Figure SW-7. The locations and numbers of surface water and sediment samples collected at each location for each seasonal event are provided in Table SW-2. The transitional season sampling event

was scheduled for March 1991, but was delayed for 2 weeks (until April) because flooding conditions caused water to overflow the banks of the surface water channel.

In accordance with the Final Work Plan (ICF 1990b; p. 3-27), two surface water and sediment samples were typically collected at the four onsite locations (2506, 2509, 2511, and 2516) in the Former Swamp/Lakebed for all three seasonal events. One surface water and sediment sample was scheduled to be collected from all onsite sample locations during the dry and wet season events. However, it was not possible to collect a surface water and sediment sample at all locations. A surface water sample was not collected at locations where surface water was not present or not present in sufficient quantity. Sediment sampling was not possible at some locations because the surface water was too deep or dense vegetation precluded sediment collection with protractible sampling techniques. Locations where surface water or sediment was not present during sampling events are indicated as "NS" in Table SW-2.

Surface water was present at all four locations sampled during the transitional event. During the dry season event, surface water was only present in Reach A and in the northern half of Reach C (see Figure SW-7). During the wet season event, surface water was present in Reach A, the southern half of Reach B, and in Reach C.

3.5 SURFACE WATER RUNOFF SAMPLING

Biweekly and stormwater runoff samples were collected from the site boundary at Location 2515, which is approximately 500 feet north of the flow monitoring station (see Figure SW-7).

3.5.1 Biweekly Runoff Sampling

Biweekly surface water sampling began in April 1991 and continued through March 1992. Because surface water flow was seldom observed at the runoff location, only four biweekly samples were collected. These biweekly samples were typically collected after long periods of rainfall. However, these samples did not meet one of the criteria established for storm event samples (i.e., no measurable precipitation for 24 hours between storm events).

3.5.2 Stormwater Runoff Sampling

A total of 12 surface water samples was scheduled to be collected at the runoff location during peak flows resulting from storm events. However, because surface water runoff was observed only during heavy continuous storms, only 1 storm-water sample was collected that met the following criteria established for storm event samples (Kennedy/Jenks/Chilton 1991e):

- Steady precipitation for at least 0.5 hours
- No measurable precipitation for 24 hours between storm events
- Only one storm event sampled per week.

3.6 ANALYTICAL PARAMETERS

Analytical parameters for all surface water and sediment samples collected during this investigation are summarized in Tables SW-3 and SW-4. Analytical results for these samples are discussed in Section 5.0 of this report and presented in Section 7.0 of the Data Appendix (Kennedy/Jenks Consultants 1992c).

TABLE SW-3

SAMPLE MATRICES, NUMBERS, TYPES, LOCATIONS, RATIONALE, AND ANALYTICAL PARAMETERS FOR THE STF SURFACE WATER AND SEDIMENT INVESTIGATION

Investigative Task	Sample Matrix	No. of Samples ^(a)	Sample Type	Sample Location ^(b)	Rationale	Analytical Parameters ^(c,d)
Background Sampling	Surface Water	10	Grab, once in the wet season and once in the dry season	Five locations within 1 mile of the site and within the South Tacoma Channel (but outside STF property boundaries)	Provide data on background surface water concentrations and evaluate possible seasonal variations	<ul style="list-style-type: none"> TCL, hardness, boron, field pH and temperature, and fecal bacteria
Runoff/Runon Surface Water Sampling <ul style="list-style-type: none"> Biweekly/Monthly Events^(a) Storm Events^(a) 	Surface Water Runoff	4 (Biweekly)	Grab from biweekly sampling location	<ul style="list-style-type: none"> Drainage ditch approximately 200 feet north of the flow monitoring station 	Evaluate quality of surface water runoff from surface water channel to offsite locations	<ul style="list-style-type: none"> TCL, hardness, field pH and temperature, fecal bacteria, boron^(f), and TSS^(g)
	Surface Water Runon	11 (Every other bi-weekly event)	Grab from monthly sampling location	<ul style="list-style-type: none"> Storm drain outlet south of pump station (City of Tacoma) 	Evaluate quality of surface water runon to the surface water channel from offsite locations	<ul style="list-style-type: none"> PAH, inorganics, hardness, field pH and temperature, fecal bacteria, boron^(f), and TSS^(g)
	Surface Water Runon	10 (Every other bi-weekly event)	Grab from monthly sampling location	<ul style="list-style-type: none"> Manhole for South 38th Street storm drain, located 50 feet west of the outlet^(h) 	Evaluate quality of surface water runon to the surface water channel from offsite sources	<ul style="list-style-type: none"> PAH, inorganics, hardness, field pH and temperature, fecal bacteria, boron^(f), and TSS^(g)
	Precipitation Runoff	1	Grab from biweekly sampling location	<ul style="list-style-type: none"> Drainage ditch approximately 200 feet north of the flow monitoring station 	Evaluate quality of surface water runoff from the surface water channel to offsite locations	<ul style="list-style-type: none"> TCL, hardness, field pH and temperature, fecal bacteria, boron^(f), and TSS^(g)
	Precipitation Runon	11	Grab from monthly sampling location	<ul style="list-style-type: none"> Storm drain outlet south of pump station (City of Tacoma) 	Evaluate quality of surface water runon to the surface water channel from offsite locations	<ul style="list-style-type: none"> PAH, inorganics, hardness, field pH and temperature, fecal bacteria, boron^(f), and TSS^(g)
	Precipitation Runon	11	Grab from monthly sampling location	<ul style="list-style-type: none"> Manhole for South 38th Street storm drain, located 50 feet west of the outlet^(h) 	Evaluate quality of surface water runon to the surface water channel from offsite sources	<ul style="list-style-type: none"> PAH, inorganics, hardness, field pH and temperature, fecal bacteria, boron^(f), and TSS^(g)

TABLE SW-3

SAMPLE MATRICES, NUMBERS, TYPES, LOCATIONS, RATIONALE, AND ANALYTICAL PARAMETERS FOR THE STF SURFACE WATER AND SEDIMENT INVESTIGATION

Investigative Task	Sample Matrix	No. of Samples ^(a)	Sample Type	Sample Location ^(b)	Rationale	Analytical Parameters ^(c,d)
Onsite Sampling (1st, 2nd, 3rd events) ⁽ⁱ⁾	Surface Water	41	Grab	Selected sampling locations (see Figure SW-7)	Quantify chemicals of concern in surface water in the surface water channel	• TCL, hardness, field pH and temperature, fecal bacteria, and boron ^(j)
	Sediment	69	Grab from water/sediment interface	Selected sampling locations (see Figure SW-7)	Quantify chemicals of concern in sediment in the surface water channel	• TCL, boron, grain size, TOC ^(k)

(a) Number of samples does not include QA/QC samples.

(b) Sample locations are shown in Figures SW-6 and SW-7. The horizontal position of each sample location was surveyed to the nearest foot.

(c) TCL - Denotes Target Compound List which includes the following analyses:

- Volatiles - EPA-CLP (EPA 1990a).
- Semivolatiles - EPA-CLP (EPA 1990a) and EPA Method 8310 for PAH.
- Pesticides and PCBs - EPA-CLP (EPA 1988b).
- Inorganics including Al, Sb, As, Ba, Be, Cd, Ca, CrIII, Total Cr, Co, Cu, Fe, Mg, Mn, Hg, Ni, K, Se, Ag, Na, Ti, V, and Zn. Inorganics are analyzed by a variety of analytical techniques outlined in the EPA-CLP (EPA 1990b); does not include CrIII and CrVI analyses for water samples. Copper will be analyzed by EPA Method 7211 for water samples.
- Total cyanide - EPA-CLP (EPA 1990b).

(d) Ancillary (non-TCL) parameters include the following analyses:

- Total suspended solids (TSS) - EPA Method 160.2.
- Boron - EPA Method 6010.
- Total organic matter (TOM) - USDA Handbook No. 60, Method 24.
- Grain size distribution (percent clay, silt, and sand) - Methods of Soil Analysis, ASA-SSSA 15-5.
- Hardness - Standard Method 2370 B.
- Fecal Bacteria: Fecal coliform - Standard Method 908C or 909C.
Fecal streptococcus - Standard Method 910A or 910B.

(e) Biweekly, monthly, and storm sampling continued through March 1992.

(f) Biweekly, monthly, and storm runoff and runoff samples were analyzed for boron beginning in September 1991.

(g) Monthly and storm runoff samples, and biweekly and storm runoff samples were analyzed for TSS beginning in November 1991.

(h) Because the outlet for the South 38th Street storm drain is submerged, the manhole located 50 feet west of the surface water channel was selected for sampling.

(i) 1st event/transitional season (April 1991); 2nd event/dry season (August 1991); 3rd event/wet season (January 1992).

(j) Surface water samples collected during the 2nd and 3rd events were analyzed for boron.

(k) Sediment samples collected during the 2nd and 3rd events were analyzed for boron and grain size distribution. In addition, 3rd event sediment samples were analyzed for total organic carbon (TOC) using TOM method.

TABLE SW-4

ANALYTICAL PARAMETERS FOR SAMPLES COLLECTED DURING STF SURFACE WATER AND SEDIMENT INVESTIGATION

Analytical Parameters ^(a)	1st Event (4/91)	2nd Event (8/91)	3rd Event (1/92)	Background Events (8/91 and 1/92)	Biweekly Events	Monthly Events	Storm Events	
							Runon	Runoff
Surface Water								
Target Compound List								
• Volatile Organic Compounds	X	X	X	X	X	X ^(b)	X ^(b)	X
• Semivolatiles (BNA and PAH)	X	X	X	X	X			X
• Pesticides/PCBs	X	X	X	X	X	X	X	X
• Metals	X	X	X	X	X			X
• Cyanide (total)	X	X	X	X	X			X
Ancillary Parameters								
• Boron ^(c)		X	X	X	X	X	X	X
• Hardness	X	X	X	X	X	X	X	X
• Fecal Bacteria	X	X	X	X	X	X	X	X
• Total Suspended Solids (TSS) ^(d)					X	X	X	X
Sediment								
Target Compound List								
• Volatile	X	X	X					
• Semivolatiles (BNA and PAH)	X	X	X					
• Pesticides/PCBs	X	X	X					
• Metals (includes CrVI)	X	X	X					
• Cyanide (total)	X	X	X					
• Moisture Content	X	X	X					
Ancillary Parameters								
• Boron ^(c)		X	X					
• Grain Size Distribution ^(e)		X	X					
• Total Organic Carbon (TOC) ^(e)			X					

(a) Table SW-3 lists analytical methods performed on surface water and sediment samples.

(b) Runon surface water samples collected for monthly and storm events were analyzed for PAH only using EPA Method 8310.

(c) Boron analysis was not required in the Final Work Plan (ICF 1990b), but was performed on both surface water and sediment samples upon EPA request.

(d) Runon surface water samples collected for monthly and storm events and runoff surface water samples collected for biweekly and storm events were analyzed for TSS beginning November 1991.

(e) Sediment samples were analyzed for TOC [using USDA Handbook No. 60, Method 24 for total organic matter (TOM)] and grain size distribution (Method ASA-SSSA15-5) for normalizing sediment concentration to account for possible spatial concentration gradients.

The Final Work Plan (ICF 1990b) required all surface water and sediment samples to be analyzed for the Target Compound List (TCL) constituents: volatiles, semivolatiles, pesticides/PCBs, inorganics, and cyanide (as well as fecal bacteria for surface water samples only). At the request of EPA, boron was added to the list of analytes. In addition, total suspended solids (TSS) analysis for surface water runoff samples, and total organic matter (TOM) and grain size analyses for sediment samples were performed to assist in data evaluation. The TCL and ancillary analytical parameters are presented in Table SW-4.

3.7 MASS LOADINGS AND FLOW MONITORING

This section describes the methods used to calculate mass loadings for surface water runoff and runoff. A discussion of continuous flow monitoring at the runoff location precedes the section on mass loadings for surface water runoff.

3.7.1 Runon Mass Loading Estimations

Runon mass loadings were estimated to evaluate the transport of chemicals of concern from upgradient surface water (i.e., Sub-basins 1 and 2) to the STF site. The method and calculations used to estimate the mass loadings for surface water runoff are presented in Appendix SW-C.

The flow rate of surface water runoff from the two storm drains was estimated for Locations 2500 and 2501 using the rational formula. Although, the rational formula is an empirically derived method used to compute runoff rates, it can also be used to calculate the volumes of stormwater runoff that result from rainfall events. These volumes and corresponding analytical data were used to approximate the loadings for chemicals of concern from upgradient sub-basins to the STF site.

The rational formula calculates the volume of stormwater runoff for an amount of rainfall using a runoff coefficient. A runoff coefficient estimates the percent of rainfall that develops into stormwater runoff (i.e., "effective runoff"). For example, high runoff coefficients are assigned to parking lots where more than 80 percent of rainfall flows off the site as stormwater. Low runoff coefficients are assigned to open grass fields where less than 10 percent of rainfall is expected to become storm water.

Sub-basin runoff coefficients were estimated for the upgradient runoff sub-basins (Sub-basins 1, 2, 2A, 2B, 2C) based on the sub-basin's land use and soil characteristics (see Section 2.2). Field verification of the calculated runoff coefficients was conducted to assess the effective runoff to the actual storm drain outfalls at Locations 2500 and 2501. Field verification indicated that the runoff coefficients calculated for Sub-basin 1, which contributes to Location 2500, were reasonable. However, Sub-basin 2, which contributes to Location 2501, is characterized by roadside ditches that have no outlets and curbs on the edges of roads that prevent water from reaching flow areas of pavement. Without an outlet, ponded runoff infiltrates the generally porous soil and does not contribute to the effective runoff to the storm drain at Location 2501. As a result, the runoff coefficient was reduced by a factor of two. This reduction of the runoff coefficient for Location 2501 is supported by the following characteristics of Sub-basin 2:

- Minimal contribution from Snake Lake (see Section 2.3.1)
- Transmissive nature of soil and rapid infiltration of precipitation and surface water.

These sub-basin characteristics allow the small 24-inch storm sewer culvert to effectively drain flow from a 165-acre basin.

Daily precipitation data were obtained for McChord AFB. Daily runoff volumes from Sub-basins 1 and 2 were calculated by the product of the runoff coefficient ("C" in the rational formula), area (acres), and the total daily rainfall. Annual loadings are equal to the total mass of stormwater runoff times the chemical concentration detected in the runoff samples. Because this method tends to overestimate total loadings, the results must be and were judiciously employed.

Loadings were estimated for several inorganic compounds. Monthly runoff concentrations were assumed to remain constant over a period (before and after sampling occurred). The monthly runoff concentrations were assumed to represent a baseline concentration for that chemical as it is present in the runoff for that specific period. The baseline concentrations were multiplied by the runoff flow rates to produce a baseline mass loading.

The stormwater runoff concentrations were assumed to represent a peak concentration for that storm event. The peak concentration was multiplied by the runoff volume for the storm event to produce a mass loading for the storm event. The mass loading for the storm event was then added to the baseline mass loading to produce the runoff mass loading to STF from the upgradient sub-basins. A summary of runoff mass loadings is presented in Section 5.5.

3.7.2 Runoff Flow Monitoring

Surface water flow was measured using continuous monitoring equipment that was installed in a storm drain (72-inch inlet pipe) west of Madison Street north of South 56th Street (all see Section 3.1.2).

The flow meter was installed in the 72-inch storm drain at Location 2517 instead of at Location 2515 (the actual site boundary) because the concrete pipe provided a uniformly shaped flow surface for which standard flow calculations could be

applied. The level and velocity of the surface water in the pipe was measured every 15 minutes and stored in the flow meter's data logger. Flow rate was calculated by the flow meter software using a standard equation for flow in a round pipe.

The runoff flow was monitored from April 1991 through March 1992 in conjunction with the biweekly and stormwater sampling events. Flow data were evaluated along with the biweekly and stormwater analytical results to calculate the transport of chemicals of concern in surface water flowing from the onsite surface water channel. The method for estimating the runoff mass loadings is discussed in Section 3.7.3.

As discussed in Section 2.3.3, offsite flow was observed to occur only after periods of heavy precipitation. Flow from the site occurred when 2 or more inches of precipitation fell within 2-6 days. The flow offsite appeared to originate as an overflow of stormwater detention within the surface water channel and may also include local runoff from the immediate area surrounding the runoff location (i.e., Location 2515). Site runoff did not occur as a result of a single storm event.

3.7.3 Runoff Mass Loadings Calculations

Runoff mass loadings were calculated to evaluate the onsite transport of chemicals of concern to the head waters at Flett Creek. The method and calculations of the surface water runoff loadings are presented in Appendix SW-E.

Runoff mass loadings were calculated using actual flow data (measured at Location 2517) and chemical concentrations detected in biweekly and stormwater runoff samples (collected at Location 2515). As discussed previously, offsite flow was observed on only four occasions, after heavy periods of rainfall. For each of these

observed offsite flows, the mass loading was calculated by multiplying the measured flow rate by the chemical concentration detected.

Because the onsite surface water channel acts as a detention basin (i.e., surface water is stored until a sufficient volume overflows as runoff), it was assumed that the detected concentration represented the average concentration of the surface water in the channel as it flowed offsite for the duration of the storm. A summary of runoff mass is presented in Section 5.6.

4.0 QUALITY ASSURANCE AND DATA VALIDATION

4.1 FIELD QA/QC PROCEDURES

During field operations, quality control (QC) samples were collected to monitor both field and laboratory operations and to evaluate the precision and accuracy of analytical data throughout the project. QC samples consisted of field duplicates and blank samples (rinsate, trip, and transfer blanks).

At a minimum, field duplicate surface water and sediment samples were collected for every 20 samples [i.e., one duplicate surface water sample was collected during the first sampling event (transitional) and two duplicate surface water and sediment samples were collected during the second (dry) and third (wet) sampling events]. One duplicate sample was collected for each biweekly, monthly, and storm sampling event. Each field duplicate was assigned a unique sample number and treated as a separate sample. These samples were not identified to the analytical laboratory as duplicates. Duplicate samples were collected in accordance with SOG-14 (Kennedy/Jenks/Chilton 1991b).

One blank sample was submitted for laboratory analysis for each day of surface water and sediment sampling. Rinsate blank samples were collected when decontamination of sampling equipment was performed (e.g., when clam shell sampler was used for sediment sampling). At a minimum, one trip blank sample was submitted for each 20 samples, one trip blank was submitted for the first sampling event and three trip blanks were submitted for both the second and third sampling events. On the remaining days of sampling, transfer blank samples were submitted for analysis.

Rinsate blanks were collected when reusing sampling equipment to monitor the effectiveness of decontamination procedures and to identify the potential for cross-

contamination between sampling locations. Rinsate blanks were collected by rinsing decontaminated sampling equipment with deionized water and placing the collected rinsate water in appropriate containers with required preservatives. Rinsate blanks were analyzed for the same constituents as the surface water or sediment samples.

Trip blanks were carried during sampling and submitted for analyses to monitor for possible volatile organic contamination caused by diffusion of organic contaminants through the septum of the sample vials during transport to and from the laboratory, as well as to monitor the quality of the laboratory water. Trip blanks were prepared by the laboratory by filling volatile organic analysis (VOA) vials with deionized water and preserving blanks with the hydrochloric acid. Trip blanks were analyzed for VOCs only.

Transfer blanks were prepared to evaluate the possibility of sample contamination from ambient conditions during the sampling event. Transfer blanks were prepared by placing high-purity deionized water in sample containers with appropriate preservatives at the sampling location. Transfer blanks were numbered using the location numbers where the blanks were prepared.

Analytical results for QC samples collected during the Surface Water and Sediment Investigation are presented in Section 7.0 of the Data Appendix. These results were evaluated by EcoChem, Inc. (EcoChem) as part of the data validation requirements (see Section 4.4) and discussions of this evaluation are presented in the Data Validation Reports (Section 8.0 of the Data Appendix).

4.2 LABORATORY QA/QC REVIEW

Analytical methods outlined in EPA's Contract Laboratory Program (CLP) Statements of Work (EPA 1988b; 1990a,b) were used to measure organic and inorganic substances. EPA's CLP methods specify QC procedures that the laboratory is expected to meet or exceed. These procedures include analysis frequency and QC limits for laboratory method blanks, spiked samples, duplicates, and laboratory control samples. Analytical results and QC criteria were evaluated by the laboratory as part of their data reduction and documentation procedures, and in accordance with those procedures outlined in the STF QAPjP (Kennedy/Jenks/Chilton 1991c). Laboratory qualifiers were assigned to data during this review as outlined in the CLP Statements of Work (EPA 1988b; 1990a,b). Descriptions of laboratory-assigned data qualifiers are presented in Section 6.0 (Tables 6-1, 6-2, and 6-3) of the Data Appendix.

4.3 INDEPENDENT QA/QC REVIEW OF LABORATORY DATA

Analytical data were received from the laboratory in hard copy or magnetic format, or both. A QA review of magnetic data was performed prior to its input into the STF database. This independent review included, at the minimum, the following activities:

- Verification of sample location numbers and laboratory accession numbers
- General review to check completeness of data packages
- Comparison of a minimum of 10 percent of magnetic data with hard copy data.

Data received in hard copy format only were manually entered into the STF database using a dual-entry or single-entry method, which was dependent on the quantity of data received. When data packages were dual-entered, a comparison program was used to check the dual-entered data for accuracy and was repeated until no discrepancies were reported (i.e., in a report of differences) between the dual-entered databases. Smaller data sets were entered into the STF database by one person and reviewed by another for errors. Once data were input into the database, a final QA review was performed.

4.4 DATA VALIDATION

Data validation of analytical results was performed to evaluate procedural compliance with QA objectives as outlined in the STF QAPjP (Kennedy/Jenks/Chilton 1991c) and to assess the laboratory's performance in meeting the QC specifications for detection limits, accuracy, precision, and completeness as outlined in the CLP Statements of Work (EPA 1988b; 1990a,b). Data validation was performed by Ecochem.

Data validation was based on the criteria described in the functional guidelines for evaluating inorganic and organic analyses (EPA 1988c,d,e). Data that did not meet required criteria were flagged with validation qualifiers. Descriptions of data validation qualifiers are presented in Section 6.0 (Tables 6-4 and 6-5) of the Data Appendix.

A 100-percent data validation was completed for all surface water and sediment analytical results. EcoChem prepared a separate Data Validation Report to summarize findings for each sampling event. These reports are presented in Section 8.0 of the Data Appendix.

4.5 DATABASE REPORT PRINTOUTS

Database files were formatted and printed as database reports on 14.5x11-inch paper. This size was selected because it allowed a 75-percent reduction to fit 8.5x11-inch paper. The format and reduction maintains data that are easily readable, allows printing 53 lines of data per sheet, and significantly reduces the size of the Data Appendices. The database report printouts (analytical results) are presented in Section 7.0 of the Data Appendix.

Two lines of data from the report header are printed at the bottom of all database reports to make paging through the reports easier. This footer indicates the database filename, date and time that file was last revised, file size, date printed, and page number.

The database report has a separate but complementary location number report (see Section 3.0 of the Data Appendix) that includes all location, survey, and sampling information [i.e., EPA Storet code, STF location number, laboratory number, NAD coordinate (northing and easting) data, and elevation].

Special report printing programs were also written to print nonstandard reports that contain ancillary information (separate from analytical data) and retain a format comparable to the database reports. These reports contain surface water monitoring field data (e.g., field observations during sample collection).

5.0 INVESTIGATIVE RESULTS

Analytical results for surface water and sediment sampling conducted during this investigation are summarized in this section. A summary of samples collected during this investigation is presented in Table SW-2 (see Section 3.0). Database printouts of the analytical results, including laboratory and data validation qualifiers, are provided in Section 7.0 of the Data Appendix (Kennedy/Jenks Consultants 1992c).

The presentation of analytical results for the Surface Water and Sediment Investigation is organized into the following subsections:

- Inorganic results
- Organic results (PAHs, VOCs, semivolatiles, and pesticides/PCBs)
- Fecal bacteria results (coliform and streptococci)
- Field measurements and observations
- Runon mass loading results
- Runoff mass loading results.

The inorganic and organic subsections are further subdivided by sample type (i.e., background, runon, onsite surface water and sediment, and runoff). Those discussions are then organized by sampling event:

- Seasonal (transitional, dry, and wet)
- Monthly/biweekly
- Storm.

Toxicity profiles published by the Agency for Toxic Substances and Disease Registry (ATSDR) were used to provide general information regarding inorganic and organic analytes detected in surface water and sediment.

For the purposes of this investigation, concentrations of the analytes detected in surface water samples collected from background locations are assumed to be representative of naturally occurring surface water quality within the South Tacoma Channel in the vicinity of the STF site. The water quality of the background locations would not be expected to represent pristine waters or naturally occurring conditions due to the urbanization of the South Tacoma Channel area.

In addition, the analytes detected in surface water are compared to 1) other corresponding sampling events (i.e., monthly to storm and seasonal events), 2) background or runoff surface water quality, 3) available information on local and regional surface water, and 4) water quality criteria for freshwater as established by EPA (1986c) for the protection of fish, shellfish, and wildlife, as well as public health and recreation.

The acute freshwater quality criteria (AFWQC) are based on a concentration that may cause acute conditions or, when noted, a 1-hour average concentration not to be exceeded more than once every 3 years on the average. The chronic FWQC are based on a concentration that may cause chronic conditions or, when noted, 4-day average concentration not to be exceeded more than once every 3 years on the average.

FWQC (acute and chronic) were calculated for seven analytes using the hardness-dependent equations as shown in Table SW-5. Based on these equations, a few of the calculated FWQC are below the contract required detection limits (CRDLs).

Analyte concentrations were compared to AFWQC. Because the grab samples collected represent a single point in time (approximately first flush for storm events) and are not representative of time composite conditions, they were compared to the 1-hour average (acute) criteria (representative of a single point in time) and not the 4-day average (chronic) criteria (representative of an extended time composite).

Analytes that were detected in transfer, trip, or rinsate blanks are discussed, where applicable, in the Data Validation Reports. Analytes that were frequently detected in blanks (e.g., methylene chloride) are discussed in the text of this report.

Duplicate analytical results are also discussed in the Data Validation Reports (Section 8.0 of the Data Appendix).

Concentrations of only those analytes detected in onsite surface water and sediment samples are presented by location in Appendix SW-D. Analytical results for onsite surface water and sediment samples collected during the dry and wet seasonal events are also presented graphically (Figures SW-8 through SW-47) for each analyte (i.e., each analyte has a dry season and a wet season figure). Surface water and sediment results are presented in these figures as plots of analyte concentration versus distance (of a sample location) from the head of the channel (Location 2500). The surface water concentration is plotted directly above the sediment concentration at each location. In addition, the hydraulic reach (i.e., A, B, C, D) and the sampling unit adjacent to the channel is shown in each of these figures. No concentrations are shown for locations where surface water samples could not be collected.

TABLE SW-5

HARDNESS-BASED EQUATIONS FOR FRESHWATER CRITERIA^(a)

Analyte	Acute and Chronic Equations ^(b)
Cadmium	Acute = $e^{(1.128 * [\ln(\text{hardness})] - 3.828)}$ Chronic = $e^{(0.7852 * [\ln(\text{hardness})] - 3.490)}$
Chromium (III)	Acute = $e^{(0.8190 * [\ln(\text{hardness})] + 3.688)}$ Chronic = $e^{(0.8190 * [\ln(\text{hardness})] + 1.561)}$
Copper	Acute = $e^{(0.9422 * [\ln(\text{hardness})] - 1.464)}$ Chronic = $e^{(0.8545 * [\ln(\text{hardness})] - 1.465)}$
Lead	Acute = $e^{(1.273 * [\ln(\text{hardness})] - 1.460)}$ Chronic = $e^{(1.273 * [\ln(\text{hardness})] - 4.705)}$
Nickel	Acute = $e^{(0.8460 * [\ln(\text{hardness})] + 3.3612)}$ Chronic = $e^{(0.8460 * [\ln(\text{hardness})] + 1.1645)}$
Silver	Acute = $e^{(1.72 * [\ln(\text{hardness})] - 6.52)}$
Zinc	Acute = $e^{(0.8473 * [\ln(\text{hardness})] + 0.8604)}$ Chronic = $e^{(0.8473 * [\ln(\text{hardness})] + 0.7614)}$

(a) Criteria in $\mu\text{g/L}$, hardness in mg/L as CaCO_3 .

(b) Acute equation is based on 1-hour average criteria. Chronic equation is based on 4-day average criteria.

Reference: U.S. EPA (1986).

5.1 INORGANIC RESULTS

The analytical results for inorganic chemicals detected in the surface water and sediment samples collected during this investigation are presented in this section. Comparisons of inorganic concentrations detected in background, runoff, onsite, and runoff surface water samples to the corresponding FWQC are presented in Tables SW-6, SW-7, SW-8, and SW-9.

Inorganic analytical results for the runoff monthly and stormwater samples collected at Locations 2500 and 2501 are presented graphically in Appendix SW-B. The FWQC for cadmium, chromium, copper, lead, nickel, silver, and zinc were calculated using hardness-dependent equations (see Table SW-5). FWQC were calculated for each background location (dry and wet seasons) using the corresponding hardness values calculated for each sample. FWQC were calculated for runoff monthly and stormwater samples using the average hardness values from those samples. The FWQC were calculated for onsite and runoff surface water using the average hardness values for the samples collected during the transitional, dry, and wet seasons, and the biweekly/monthly and storm events, respectively.

Sediment samples collected during the dry and wet season events were analyzed for percent grain size. In addition, sediment samples collected during the wet season were analyzed for total organic matter (TOM). Grain size and TOM analyses were performed to obtain data related to the physical characteristics of onsite sediment. Results of these analyses are presented in Appendix SW-F. As discussed in the next paragraph, results of the grain size analyses were used to normalize dry weight concentrations of inorganic analytes detected in sediment samples.

Onsite sediment dry weight concentrations of inorganics were normalized to percent fine-grain material (i.e., clay plus silt fractions) measured in the sample. For each sample, normalized concentrations were calculated by dividing dry weight inorganic concentrations by the amount of fine-grain material in the sample. Fine-

TABLE SW-6

INORGANIC ANALYTICAL RESULTS FOR BACKGROUND SURFACE WATER COMPARED TO WATER QUALITY CRITERIA

Analyte	Freshwater Quality Criteria ($\mu\text{g/L}$) ^(a)		Dry Season Sampling Event (August 1991)			Wet Season Sampling Event (January 1992)		
	Acute or 1-Hour Average ^(b)	Chronic or 4-Day Average ^(c)	Minimum Concentration ($\mu\text{g/L}$)	Maximum Detected Concentration ($\mu\text{g/L}$)	Number of Exceedances of Acute Criteria	Minimum Concentration ($\mu\text{g/L}$)	Maximum Detected Concentration ($\mu\text{g/L}$)	Number of Exceedances of Acute Criteria
Aluminum	750 ^(d)	87 ^(d)	B 47.6	392	0	B 28.8 J4	1,980 J4	1
Antimony	9,000	610 ^(d)	U 20	B 20	0	U 11	B 12.7	0
Arsenic	1,210 ^(e)	238 ^(e)	U 2.0	ND	0	B 1.2	B 3.6	0
Barium	NC	NC	B 7.5 UJ	B 28.0 J4	NC	B 5.1 UJ	B 26.9	NC
Beryllium	130	5.3	U 1.0	ND	0	U 1.0	ND	0
Boron	NC	NC	U 19.0	B 66.3	NC	U 8.7	B 36.1	NC
Cadmium ^(f)	0.6-13.3 ^(g) 0.4-10.9	0.3-2.7 ^(g) 0.2-2.3	U 2.0	ND	0	U 1.0	ND	0
Calcium	NC	NC	5,900	79,600	NC	B 4,240	76,700	NC
Chromium (Total) ^(f,h)	451-4,230 ^(g) 351.2-3,666	63-513 ^(g) 51-446	U 5.0	B 9.89	0	U 5.0	ND	0
Cobalt	NC	NC	U 5.0	ND	NC	U 3.0	ND	NC
Copper ^(f)	3.6-49.1 ^(g) 2.7-41.7	2.8-29.8 ^(g) 2.1-25.7	B 1.4	11.8 J4	1	U 1.0	B 11.2	0
Cyanide	22	5.2	U 10.0	ND	0	U 10.0	ND	0
Iron	NC	1,000	372 UJ	1,220	0	B 76.1	1,990	0
Lead ^(f)	9.6-323.8 ^(g) 6.3-259.1	0.4-12.6 ^(g) 0.3-10.1	B 1.7 UJ	19.3	0	B 2.2 UJ	ND	0
Magnesium	NC	NC	B 949	39,900	NC	B 687	33,600	NC
Manganese	NC	NC	27.3	1,820	NC	U 1.0	1,440	NC

TABLE SW-6

INORGANIC ANALYTICAL RESULTS FOR BACKGROUND SURFACE WATER COMPARED TO WATER QUALITY CRITERIA

Analyte	Freshwater Quality Criteria (µg/L) ^(a)		Dry Season Sampling Event (August 1991)			Wet Season Sampling Event (January 1992)		
	Acute or 1-Hour Average ^(b)	Chronic or 4-Day Average ^(c)	Minimum Concentration (µg/L)	Maximum Detected Concentration (µg/L)	Number of Exceedances of Acute Criteria	Minimum Concentration (µg/L)	Maximum Detected Concentration (µg/L)	Number of Exceedances of Acute Criteria
Mercury	2.4 ⁽ⁱ⁾	0.012 ⁽ⁱ⁾	U 0.20	ND	0	U 0.20	ND	0
Nickel ^(f)	342.4-3,543 ^(g) 259-3,055	38.1-393.9 ^(g) 28.8-339.7	U 15.0	ND	0	U 8.0	ND	0
Potassium	NC	NC	B 2,090	5,840	NC	B 1,300 UJ	B 3,380	NC
Selenium	20	5	U 3.0	U 30.0 UJ	0	U 1.0 UJ	U 2.0	0
Silver ^(f)	0.23-26.1 ^(d,g,j) 0.13-19.3 ^(d,j)	0.1 ^(g) 0.1	U 4.0	ND	0	U 6.0	ND	0
Sodium	NC	NC	B 2,760 UJ	56,200	NC	B 1,600	12,300	NC
Thallium	1,400	40	U 1.0	ND	0	U 2.0	ND	0
Vanadium	NC	NC	U 6.0	ND	NC	B 4.8	B 9.1	NC
Zinc ^(f)	28.2-292.8 ^(g) 21.3-252.4	25.5-265.2 ^(g) 19.3-228.6	B 8.2 UJ	75.7	1	B 11.1 UJ	96.4	1

- (a) U.S. EPA (1986).
(b) 1-hour average not exceeded more than once every 3 years on the average.
(c) 4-day average not exceeded more than once every 3 years on the average.
(d) Draft Water Quality Standards for Surface Waters of the State of Washington (WAC 173-201, 1988).
(e) Total of Arsenic III and Arsenic V criteria.
(f) Criteria based on equations listed in Table SW-5. Minimum and maximum water quality criteria were calculated using the minimum and maximum hardness measured for background surface water samples.
(g) First range of numbers are minimum and maximum values for dry season. Second range of numbers are minimum and maximum values for wet season.
(h) Total of Chromium VI and Chromium III.
(i) Listed as Mercury II.
(j) Maximum value for grab sample.
NC No criteria.
ND Not detected.

TABLE SW-7

INORGANIC ANALYTICAL RESULTS FOR RUNON SURFACE WATER COMPARED TO WATER QUALITY CRITERIA

Analyte	Freshwater Quality Criteria (µg/L) ^(a)		Monthly Sampling Events						Storm Sampling Events					
	Acute or 1-Hour Average ^(b)	Chronic or 4-Day Average ^(c)	Location 2500		Location 2501		Number of Exceedances of Acute Criteria		Location 2500		Location 2501		Number of Exceedances of Acute Criteria	
			Minimum Conc. (µg/L)	Maximum Detected Conc. (µg/L)	Minimum Conc. (µg/L)	Maximum Detected Conc. (µg/L)	Location 2500	Location 2501	Minimum Conc. (µg/L)	Maximum Detected Conc. (µg/L)	Minimum Conc. (µg/L)	Maximum Detected Conc. (µg/L)	Location 2500	Location 2501
Aluminum	750 ^(d)	87 ^(d)	U 35.0	3,180	B 35.7 UJ	25,200	3	8	402	4,630	2,830	38,500	8	11
Antimony	9,000	610 ^(d)	B 15.9	B 15.9	U 11.0	ND	0	0	U 11.0	ND	U 11.0	ND	0	0
Arsenic	1,210 ^(e)	238 ^(e)	U 1.0	19.5	U 1.0	B 5.5	0	0	U 1.0	B 6.3 J4	B 1.2	25.2	0	0
Barium	NC	NC	B 4.0	B 25.6	B 13.9	B 176	NC	NC	B 10.2	B 48.3	B 52.9	252.0	NC	NC
Beryllium	130	5.3	U 1.0	ND	U 1.0	ND	0	0	U 1.0	ND	U 1.0	ND	0	0
Boron	NC	NC	U 17.8	B 46.9	U 17.8	174.4	NC	NC	U 7.0 UJ	36.4	U 17.8	102	NC	NC
Cadmium ^(f)	1.7 ^(g) 1.0	0.6 ^(g) 0.4	U 1.0	ND	U 1.0	ND	0	1	U 1.0	ND	U 1.0	ND	0	0
Calcium	NC	NC	6,510	21,900	B 3,870	16,300	NC	NC	B 2,500	8,030	B 3,980	15,900	NC	NC
Chromium (Total) ^(f,h)	983.2 ^(g) 651	126.3 ^(g) 86.8	U 3.3	B 7.2	U 3.3	34.9	0	0	U 4.0	12.6	U 4.0	50.4	0	0
Cobalt	NC	NC	U 3.0	997.0	U 3.0	B 15.2	NC	NC	U 3.0	ND	U 5.0	B 15.0	NC	NC
Copper ^(f)	9.0 ^(g) 5.6	6.4 ^(g) 4.2	B 5.4	38.5	B 3.7 UJ	46.1	4	2	7.0	52.2 J4	14	48.6	11	11
Iron	NC	1,000	B 58.4 UJ	3,830	B 94.1 UJ	22,500	0	0	634	4,160	2,510	26,500	0	0
Lead ^(f)	32.9 ^(g) 17.1	1.3 ^(g) 0.7	B 1.2 UJ	77.7 J4	B 1.7 UJ	40.9 J4	1	1	15.6 J4	95.6	16.3 J4	124	9	10
Magnesium	NC	NC	B 1,340	13,700	B 1,210	8,710	NC	NC	B 758	B 3,110	B 1,570	8,260	NC	NC
Manganese	NC	NC	B 2.9 UJ	121	B 6.7 J4	659	NC	NC	19.9	113.0	186	453.0	NC	NC
Mercury	2.4 ⁽ⁱ⁾	0.012 ⁽ⁱ⁾	U 0.10	ND	ND	U 0.2	0	0	U 0.1	0.25	B 0.14	0.31	0	0
Nickel ^(f)	774.8 503	86.1 55.9	U 6.7	ND	U 6.7	52.6	0	0	B 7.8	B 7.8	U 14.0	49.0	0	0
Potassium	NC	NC	B 2,450	14,500	B 926	6,320	NC	NC	B 914	B 3,560 J4	B 1,070 UJ	5,580	NC	NC

TABLE SW-7

INORGANIC ANALYTICAL RESULTS FOR RUNON SURFACE WATER COMPARED TO WATER QUALITY CRITERIA

Analyte	Freshwater Quality Criteria (µg/L) ^(a)		Monthly Sampling Events							Storm Sampling Events					
	Acute or 1-Hour Average ^(b)	Chronic or 4-Day Average ^(c)	Location 2500		Location 2501		Number of Exceedances of Acute Criteria		Location 2500		Location 2501		Number of Exceedances of Acute Criteria		
			Minimum Conc. (µg/L)	Maximum Detected Conc. (µg/L)	Minimum Conc. (µg/L)	Maximum Detected Conc. (µg/L)	Location 2500	Location 2501	Minimum Conc. (µg/L)	Maximum Detected Conc. (µg/L)	Minimum Conc. (µg/L)	Maximum Detected Conc. (µg/L)	Location 2500	Location 2501	
Selenium	20	5	U 1.0	B 4.6 J4	U 1.0	ND	0	0	U 1.0	B 1.9	U 1.0	8.4	0	0	
Silver ^(f)	1.2 ^(d,g,i) 0.5 ^(d,i)	0.1 ^(g) 0.1	U 3.0	ND	U 3.0	ND	0	0	U 3.0	B 3.5	U 3.0	ND	1	0	
Sodium	NC	NC	U 533	453,000	B 2,100	12,600	NC	NC	10,900	52,900	B 2,540	9,660	NC	NC	
Thallium	1,400	40	U 1.0	19.5	U 1.0	ND	0	0	U 1.0	ND	U 1.0	ND	0	0	
Vanadium	NC	NC	U 3.3	B 7.2	U 3.3	B 48.1	NC	NC	U 4.0	B 9.4	B 8.2 UJ	66.9	NC	NC	
Zinc ^(f)	63.9 ^(g) 41.4	57.9 ^(g) 37.5	B 17.4 UJ	271	B 19.2	171	5	2	82	325	57.5	241	11	11	

- (a) U.S. EPA (1986).
 (b) 1-hour average not exceeded more than once every 3 years on the average.
 (c) 4-day average not exceeded more than once every 3 years on the average.
 (d) Draft Water Quality Standards for Surface Waters of the State of Washington (WAC 173-201, 1988).
 (e) Total of Arsenic III and Arsenic V criteria.
 (f) Criteria based on equations listed in Table SW-5. An average hardness of monthly runon values and an average hardness of stormwater runon values was used to calculate criteria. Based on 21 samples, the average hardness for monthly runon was 48.64 mg/L. Based on 22 samples, the average hardness for stormwater runon was 29.33 mg/L.
 (g) First number is value for monthly event; second number is value for storm event.
 (h) Total of Chromium VI and Chromium III.
 (i) Listed as Mercury II.
 (j) Maximum value for grab sample.
 NC No criteria.
 ND Not detected.

TABLE SW-8

INORGANIC ANALYTICAL RESULTS FOR ONSITE SURFACE WATER COMPARED TO WATER QUALITY CRITERIA

Analyte	Freshwater Quality Criteria ($\mu\text{g/L}$) ^(a)		Transitional Season Sampling Event (April 1991)			Dry Season Sampling Event (August 1991)			Wet Season Sampling Event (January 1992)		
	Acute or 1-Hour Average ^(b)	Chronic or 4-Day Average ^(c)	Minimum Conc. ($\mu\text{g/L}$)	Maximum Detected Conc. ($\mu\text{g/L}$)	Number of Exceedances of Acute Criteria	Minimum Conc. ($\mu\text{g/L}$)	Maximum Detected Conc. ($\mu\text{g/L}$)	Number of Exceedances of Acute Criteria	Minimum Conc. ($\mu\text{g/L}$)	Maximum Detected Conc. ($\mu\text{g/L}$)	Number of Exceedances of Acute Criteria
Aluminum	750 ^(d)	87 ^(d)	B 85.3 UJ	2,510	1	201 UJ	80,900	5	309	5,990	11
Antimony	9,000	610 ^(d)	U 43.3	ND	0	U 20	ND	0	U 11	ND	0
Arsenic	1,210 ^(e)	238 ^(e)	B 3.3	4.0 J4	0	U 2.0	24.8	0	U 1.0	B 8.0	0
Barium	NC	NC	B 11.0	B 37.5	NC	B 10.9 UJ	773 J4	NC	B 9.9	B 43.5	NC
Beryllium	130	5.3	U 1.1	ND	0	U 1.0	B 1.9	0	U 1.0	ND	0
Boron	NC	NC	NA	NA	NC	U 19	B 34.6	NC	U 15.3	B 47.4	NC
Cadmium ^(f)	2.7 ^(g) 1.2	0.9 ^(g) 0.5	U 1.1	ND	0	U 2.0	18.3	1	U 1.0	ND	0
Calcium	NC	NC	6,460	59,300	NC	11,400	39,500	NC	B 4,960	14,600	NC
Chromium (Total) ^(f,h)	1,341 ^(g) 768	168.6 ^(g) 100.6	U 3.3 UJ	ND	0	U 5.0	193.0	0	U 5.0	15.5	0
Cobalt	NC	NC	U 6.7	ND	NC	U 5.0	B 24.1	NC	U 3.0	B 7.7	NC
Copper ^(f)	13.0 ^(g) 6.8	8.9 ^(g) 4.9	B 2.0 UJ	ND	0	B 5.2	2,980	5	B 3.8	B 61.1 J4	13
Cyanide	22	5.2	U 10.0	ND	0	U 10	ND	0	U 10	14.2 J3	0
Iron	NC	1,000	292 J4	1,960 J4	0	427	58,700	0	516	4,910	0
Lead ^(f)	53.4 ^(g) 22.2	2.1 ^(g) 0.9	B 2.2 UJ	8.3	0	U 1.0	107	2	3.4 UJ	219 J4	9
Magnesium	NC	NC	B 1,720	10,100 J4	NC	B 1,290	24,400	NC	B 1,430	7,350	NC
Manganese	NC	NC	B 16.0 UJ	711	NC	46.4	865	NC	B 8.5 UJ	132	NC
Mercury	2.4 ^(h)	0.01 ^(h)	U 0.1	ND	0	U 0.2	0.49	0	U 0.2	0.28	0

TABLE SW-8

INORGANIC ANALYTICAL RESULTS FOR ONSITE SURFACE WATER COMPARED TO WATER QUALITY CRITERIA

Analyte	Freshwater Quality Criteria ($\mu\text{g/L}$) ^(a)		Transitional Season Sampling Event (April 1991)			Dry Season Sampling Event (August 1991)			Wet Season Sampling Event (January 1992)		
	Acute or 1-Hour Average ^(b)	Chronic or 4-Day Average ^(c)	Minimum Conc. ($\mu\text{g/L}$)	Maximum Detected Conc. ($\mu\text{g/L}$)	Number of Exceedances of Acute Criteria	Minimum Conc. ($\mu\text{g/L}$)	Maximum Detected Conc. ($\mu\text{g/L}$)	Number of Exceedances of Acute Criteria	Minimum Conc. ($\mu\text{g/L}$)	Maximum Detected Conc. ($\mu\text{g/L}$)	Number of Exceedances of Acute Criteria
Nickel ^(f)	1,073 ^(g) 597.4	119 ^(g) 66.4	U 6.7	B 9.9	0	U 15.0	ND	0	U 8.0	B 18.4	0
Potassium	NC	NC	B 1,630	B 4,490	NC	B 2,280	11,500	NC	B 1,330 UJ	B 3,870	NC
Selenium	20	5	U 2.2	B 3.1	0	U 3.0	ND	0	U 1.0 UJ	B 2.2	0
Silver ^(f)	2.3 ^(d,g,i) 0.7 ^(d,i)	0.1 ^(g) 0.1	U 6.7	B 10.8	1	U 4.0	ND	0	U 6.0	ND	0
Sodium	NC	NC	15,500	77,100	NC	19,200	176,000	NC	B 1,880	35,900	NC
Thallium	1,400	40	U 7.8	ND	0	U 1.0	ND	0	U 2.0	ND	0
Vanadium	NC	NC	U 3.3	ND	NC	U 6.0	146	NC	U 4.0	B 14.8	NC
Zinc ^(f)	88.3 ^(g) 49.2	79.9 ^(g) 44.6	B 4.9 UJ	ND	0	35.7	3,160	3	B 12.5 UJ	215	17

(a) U.S. EPA (1986).

(b) 1-hour average not exceeded more than once every 3 years on the average.

(c) 4-day average not exceeded more than once every 3 years on the average.

(d) Draft Water Quality Standards for Surface Waters of the State of Washington (WAC 173-201, 1988).

(e) Total of Arsenic III and Arsenic V criteria.

(f) Criteria based on equations listed in Table SW-5. An average hardness of onsite values was used to calculate criteria. Average hardness for transitional and dry seasons was 71.7 mg/L and 36 mg/L for wet season.

(g) First number is value for transitional and dry seasons; second number is value for wet season.

(h) Total of Chromium VI and Chromium III.

(i) Listed as Mercury II.

(j) Maximum value for grab sample.

NC No criteria.

NA Not analyzed.

ND Not detected.

TABLE SW-9

Page 1 of 2

INORGANIC ANALYTICAL RESULTS FOR RUNOFF SURFACE WATER COMPARED TO WATER QUALITY CRITERIA

Analyte	Freshwater Quality Criteria ($\mu\text{g/L}$) ^(a)		Biweekly Sampling Events		Storm Sampling Event (1/28/92)	Number of Exceedances of Acute Criteria
	Acute or 1-Hour Average ^(b)	Chronic or 4-Day Average ^(c)	Minimum Conc. ($\mu\text{g/L}$)	Maximum Detected Conc. ($\mu\text{g/L}$)		
Aluminum	750 ^(d)	87 ^(d)	843	4,040	1,200	5
Antimony	9,000	610 ^(d)	U 11.0	ND	U 11.0	0
Arsenic	1,210 ^(e)	238 ^(e)	U 1.0	B 4.0	B 1.4	0
Barium	NC	NC	B 15.7	B 31.2	B 16.8	NC
Beryllium	130	5.3	U 1.0	ND	U 1.0	0
Boron	NC	NC	U 7.0	B 39.8	25.8 UJ	NC
Cadmium ^(f)	0.7	0.4	U 1.0	ND	U 1.0	0
Calcium	NC	NC	B 3,830	6,790	7,200	NC
Chromium (Total) ^(f,g)	530	72.3	U 4.0	B 8.0	U 7.0	0
Cobalt	NC	NC	U 3.0	ND	U 3.0	NC
Copper ^(f)	4.4	3.3	B 4.7 UJ	9.2	B 5.6	4
Cyanide	22	5.2	U 10.0	ND	U 10.0	0
Iron	NC	1,000	1,040	2,610	1,290	NC
Lead ^(f)	12.3	0.5	B 2.7 J4	9.5 J4	4.5 UJ	0
Magnesium	NC	NC	B 1,230	B 1,910	B 2,170	NC
Manganese	NC	NC	21.1	52.6	29.0	NC

TABLE SW-9

Page 2 of 2

INORGANIC ANALYTICAL RESULTS FOR RUNOFF SURFACE WATER COMPARED TO WATER QUALITY CRITERIA

Analyte	Freshwater Quality Criteria (µg/L) ^(a)		Biweekly Sampling Events		Storm Sampling Event (1/28/92)	Number of Exceedances of Acute Criteria
	Acute or 1-Hour Average ^(b)	Chronic or 4-Day Average ^(c)	Minimum Conc. (µg/L)	Maximum Detected Conc. (µg/L)		
Mercury	2.4 ^(h)	0.01 ^(h)	B 0.10 UJ	ND	U 0.20	0
Nickel ^(f)	403	44.8	B 6.8	B 10.1	B 15.3 UJ	0
Potassium	NC	NC	B 1,130	B 2,350	B 1,950	NC
Selenium	20	5	U 1.0	ND	U 1.0	0
Silver ^(f)	0.3 ^(d,i)	0.1	U 3.0	ND	U 6.0	0
Sodium	NC	NC	B 2,090	14,700	16,200	NC
Thallium	1,400	40	U 1.0	ND	U 2.0	0
Vanadium	NC	NC	U 3.3	B 4.2	U 4.0	NC
Zinc ^(f)	33.2	30.1	22.4	40.4	48.0	4

(a) U.S. EPA (1986).

(b) 1-hour average not exceeded more than once every 3 years on the average.

(c) 4-day average not exceeded more than once every 3 years on the average.

(d) Draft Water Quality Standards for Surface Waters of the State of Washington (WAC 173-201, 1988).

(e) Total of Arsenic III and Arsenic V criteria.

(f) Criteria based on equations listed in Table SW-5. An average hardness (22.6) of four runoff values was used to calculate criteria.

(g) Total of Chromium VI and Chromium III.

(h) Listed as Mercury II.

(i) Maximum value for grab sample.

NC No criteria.

ND Not detected.

grain normalized concentrations are shown at the same locations as the dry weight normalized concentration. Sediment concentrations were normalized to percent fine-grain material in an effort to account for variations in the physical properties of the sediment. These variations may be a result of natural heterogeneity of soil, discharges of surface water runoff, physical disturbances (water velocity, intermittent surges), seasonal water fluctuations, and channel configuration. For instance, fine-grain sediment will be transported out of portions of the channel where high water velocities or other disturbances occur. Conversely, fine-grain sediment may accumulate in portions of the channel that are quiescent. In addition, the percent fine-grain material will typically increase with distance from a source (assuming no other disturbances within the channel). Identifying these sediment and receiving water characteristics are important factors in trend analysis, source identification, and mass transport evaluations. Typically, inorganics adhere to fine-grain material because of the greater surface areas associated with the smaller particle sizes relative to larger particle sizes (e.g., sand and gravel).

Fine-grain normalized concentrations will be used in this report, when appropriate, to assist in sediment data evaluation and trend analysis. No attempt will be made, nor is it appropriate, to relate these normalized concentrations to regulatory criteria, potential human health risks, or environmental impacts.

5.1.1 Aluminum

The most common of the aluminum-enriched sedimentary materials are clays, which are present in most natural water environments (Hem 1989). Aluminum is a major component of clay materials and it rarely occurs in concentrations greater than a few tenths or hundredths of milligrams per liter (mg/L). Elevated concentrations have been observed in runoff and lake waters in areas affected by precipitation that has low pH ("acid rain") (Hem 1989). Aluminum was detected at concentrations above 4,000 $\mu\text{g/L}$ in samples collected during a heavy flow of a leachate/runoff

seep from a catch basin in the Leach Creek area in January 1983 (Lum and Turney 1985).

5.1.1.1 Background. Aluminum was detected in samples collected at all five background locations during the dry and wet season sampling events. Aluminum concentrations ranged from 28.8 $\mu\text{g/L}$ to 1,980 $\mu\text{g/L}$ (see Table SW-6). One sample contained a reported concentration (1,980 $\mu\text{g/L}$) that exceeded the 1-hour average WQC (750 $\mu\text{g/L}$) for aluminum. That sample was collected during the wet season at Location 2541.

At four of the five background surface water locations, dry season aluminum concentrations were higher than those detected in the wet season samples. At Location 2541, the wet season aluminum concentration exceeded the dry season concentration.

5.1.1.2 Runon. Aluminum was detected in all monthly runon samples collected from both sampling locations (see Table SW-7). The monthly runon aluminum concentrations ranged from undetected to 3,180 $\mu\text{g/L}$ at Location 2500 and from undetected to 25,200 $\mu\text{g/L}$ at Location 2501. The monthly runon concentrations exceeded the 1-hour average criteria (750 $\mu\text{g/L}$) in three samples collected at Location 2500 and in eight samples collected at Location 2501.

Aluminum was detected in all stormwater runon samples collected from both runon locations. The stormwater runon concentrations ranged from 402 $\mu\text{g/L}$ to 4,630 $\mu\text{g/L}$ at Location 2500 and from 2,830 $\mu\text{g/L}$ to 38,500 $\mu\text{g/L}$ at Location 2501. The stormwater runon concentrations exceeded the 1-hour average WQC in 8 and 11 samples collected at Locations 2500 and 2501, respectively.

Generally, aluminum concentrations in stormwater runon samples were higher at both locations than those detected in monthly runon samples, and the monthly and storm concentrations detected at Location 2501 were higher than those values detected at Location 2500 (see Appendix SW-B). Seasonal variations were

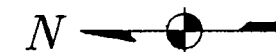
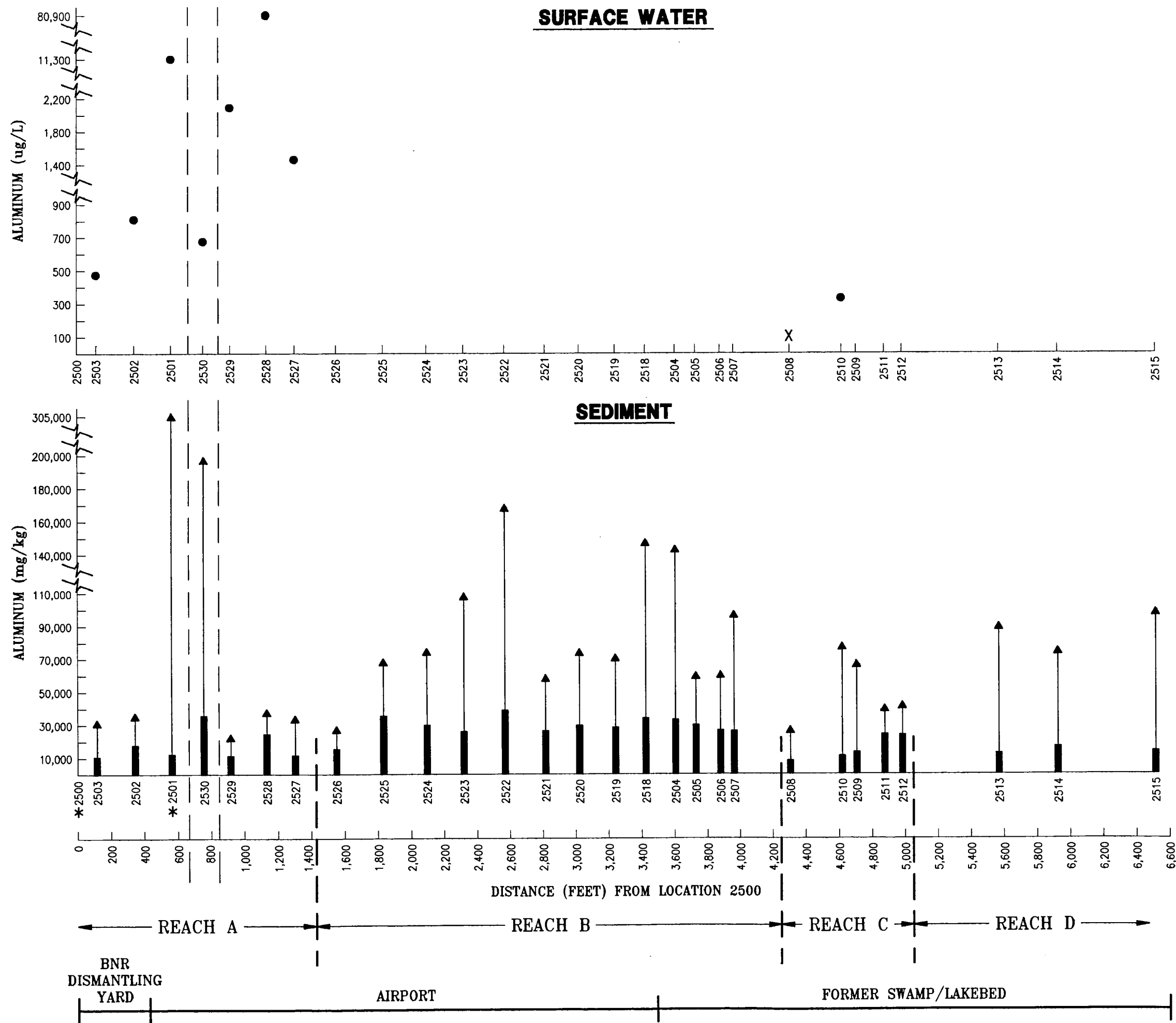
apparent with aluminum concentrations increasing during the months of June to October at both locations. The one exception includes the high concentrations of aluminum detected in the samples collected during the 100-year storm on 4 April 1991.

Concentrations of aluminum detected in the surface water runon samples generally exceeded the range of background concentrations at Location 2501 with four exceedances at Location 2500. Aluminum concentrations detected in all runon samples were within the reported surface water aluminum concentrations detected in natural surface waters (100,000 $\mu\text{g/L}$; Hem 1989). However, the stormwater runon concentrations of aluminum were greater than the surface water concentrations detected in the USGS study (Lum and Turney 1985).

5.1.1.3 Onsite Surface Water. Concentrations of aluminum in onsite surface water (see Table SW-8) and sediment samples collected during the transitional season are presented in Appendix SW-D. Aluminum was detected in onsite surface water at Locations 2509 and 2516. Aluminum concentrations ranged from undetected to 2,510 $\mu\text{g/L}$ (Location 2509). The AFWQC for aluminum (750 $\mu\text{g/L}$) was exceeded at Location 2509.

Concentrations of aluminum in onsite surface water and sediment samples collected during the dry season are presented in Appendix SW-D and Figure SW-8. Aluminum concentrations ranged from undetected to 80,900 $\mu\text{g/L}$ (Location 2528) during this sampling event. The highest aluminum concentrations were detected in samples collected in Reach A and the maximum concentration was detected at Location 2528 in Reach A. The AFWQC was exceeded at five locations in Reach A. Aluminum concentrations for two onsite surface water samples (Locations 2501 and 2528) exceeded the maximum concentration detected for runon surface water samples (38,500 $\mu\text{g/L}$).

Concentrations of aluminum in onsite surface water and sediment samples collected during the wet season are presented in Appendix SW-D and Figure SW-9.



LEGEND

- SURFACE WATER CONCENTRATION
- DRY-WEIGHT NORMALIZATION
- ▲ FINE-GRAIN NORMALIZATION
- X 1/2 DETECTION LIMIT
- * SURFACE WATER RUNON LOCATION

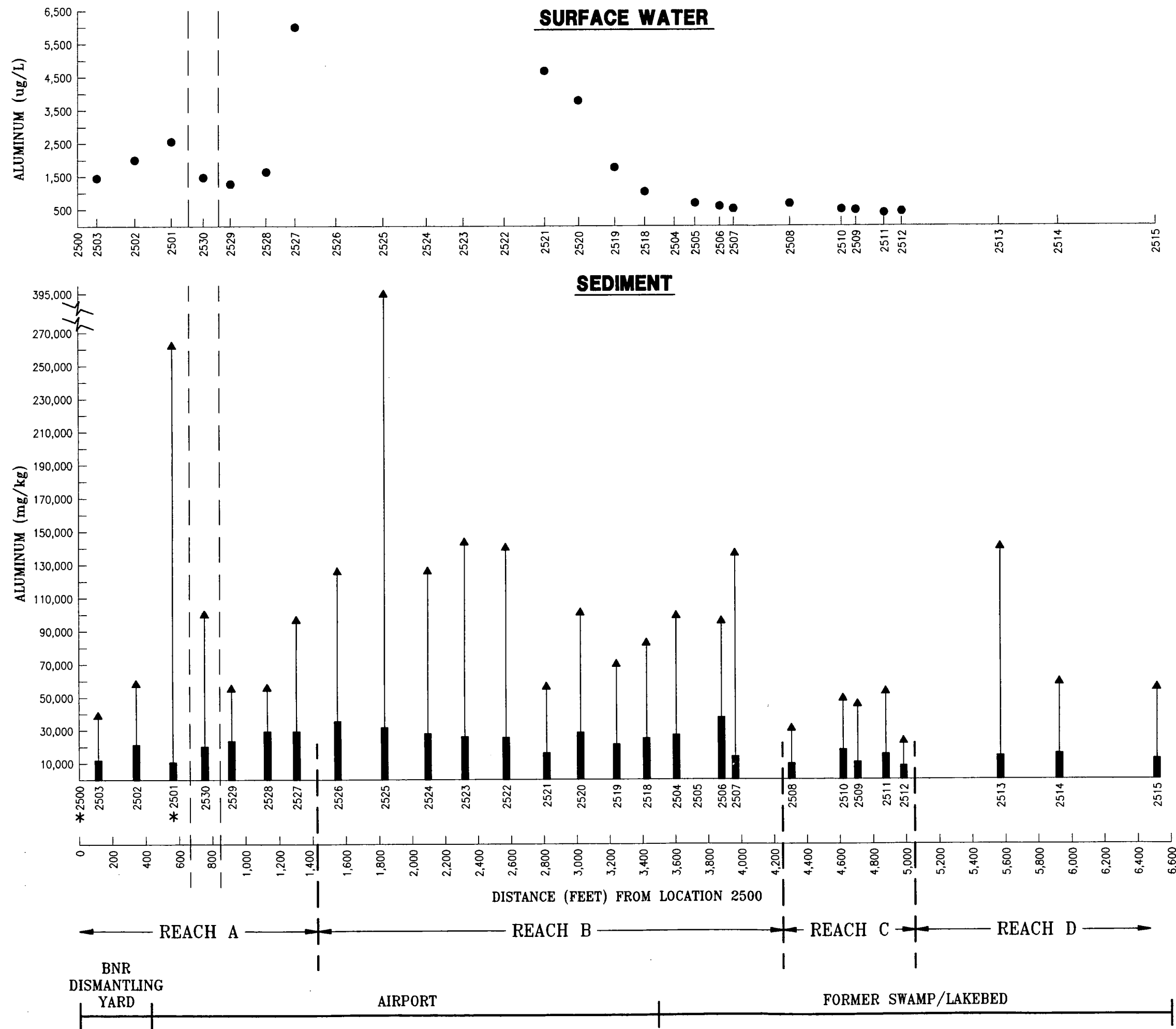
Kennedy/Jenks Consultants

SOUTH TACOMA FIELD
TACOMA, WA

**ALUMINUM CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (DRY SEASON, AUGUST 1991)**

916055.24/P2SK012

FIGURE SW-8



LEGEND

- SURFACE WATER CONCENTRATION
- DRY-WEIGHT NORMALIZATION
- ▲ FINE-GRAIN NORMALIZATION
- X 1/2 DETECTION LIMIT
- * SURFACE WATER RUNON LOCATION

Kennedy/Jenks Consultants

SOUTH TACOMA FIELD
TACOMA, WA

**ALUMINUM CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (WET SEASON, JANUARY 1992)**

916055.24/P2SK035

FIGURE SW-9

Aluminum was detected in wet season samples collected from all locations. Concentrations of aluminum ranged from 309 $\mu\text{g/L}$ at Location 2511 to 5,990 $\mu\text{g/L}$ at Location 2527. Generally, the highest concentrations of aluminum were detected in samples collected from the south-central portion of Reach B and in Reach A in the vicinity of the 38th Street 24-inch discharge (Location 2501). Aluminum concentrations exceeded the AFWQC at 11 locations. The maximum runoff surface water concentration was not exceeded at any location during the wet season event.

Maximum aluminum concentrations in surface water were approximately two to five times greater in the dry season compared to the wet and transitional seasons. The aluminum concentrations detected in all onsite surface water samples were within the reported surface water aluminum concentrations detected in natural waters (100,000 $\mu\text{g/L}$; Hem 1989). However in four onsite surface water samples, concentrations of aluminum were greater than those concentrations detected in the USGS study (Lum and Turney 1985).

5.1.1.4 Onsite Sediment. Aluminum was detected in onsite sediment samples collected at all four locations during the transitional season. Aluminum concentrations ranged from 8,660 mg/kg at Location 2516 (one of two samples collected in the grid assigned this location number) to 30,100 mg/kg at Location 2506.

During the dry season, aluminum was detected in onsite sediment samples collected from all locations. Aluminum concentrations ranged from 5,690 mg/kg at Location 2509 (one of the two samples collected in the grid assigned this location number) to 38,700 mg/kg at Location 2522. Generally, dry weight aluminum concentrations in Reaches B and D were fairly uniform. When normalized to percent fine-grain material, the maximum aluminum concentrations were detected in samples collected from Locations 2501 and 2530 in Reach A, where percentages of fine-grain material were low (4 and 18 percent, respectively). In Reach D, normalized aluminum concentrations increased substantially compared with dry

weight concentrations because of the relatively low percent fine-grain material in these samples (i.e., 14 to 22 percent). No gradients or trends were apparent in aluminum concentrations for sediment samples collected from Reaches B and C.

During the wet season, aluminum was detected in onsite sediment samples collected from all locations. Aluminum concentrations ranged from 7,480 mg/kg at Location 2509 (one of the two sample collected in the grid assigned this location number) to 37,600 mg/kg at Location 2506. The lowest aluminum concentration (3,410 mg/kg) was detected at Location 2516. Generally, dry weight concentrations were fairly constant in Reaches A and B before declining to lower concentrations in Reaches C and D. When normalized to percent fine-grain material, aluminum concentrations were the most elevated in Reaches A and B (the northern section). Normalized concentrations decreased for the remainder of Reach B and all of Reach C before increasing in Reach D. Sediment concentrations of aluminum did not vary considerably between seasonal sampling events.

5.1.1.5 Runoff. Aluminum was detected in all runoff biweekly surface water and stormwater samples collected from Location 2515. The biweekly surface water runoff concentrations ranged from 843 $\mu\text{g/L}$ to 4,040 $\mu\text{g/L}$ (see Table SW-9). The stormwater runoff concentration was 1,200 $\mu\text{g/L}$. All of the detected concentrations exceeded AFWQC. However, runoff concentrations were within the range of runoff concentrations except for one biweekly runoff concentration which was greater than the range of detected concentrations at Location 2500. That one biweekly runoff concentration (4,040 $\mu\text{g/L}$) was also above the concentration detected in the Leach Creek area (Lum and Turney 1985).

5.1.2 Antimony

Antimony is a semi-metal or metalloid that is generally detected at very low concentrations in natural waters. Antimony concentrations, ranging from 2.6 $\mu\text{g/L}$

to 23 $\mu\text{g/L}$, were detected in runoff samples collected during the National Urban Runoff Program (ATSDR 1990a).

Antimony occurs in surface water in the form of a particulate matter (antimony or antimony-containing compounds) or adsorbed to particulate matter. When released into waterways, antimony is transported to and settles in areas of active sedimentation. Antimony's adsorption to sediment is primarily correlated with the iron, manganese, and aluminum content of sediment; it co-precipitates with hydroxylated oxides of these elements. The range of antimony concentrations in sediment samples from across the U.S. is 0.5-17.5 mg/kg (ATSDR 1990a).

During this investigation, antimony was detected in samples collected from background surface water and onsite sediment (i.e., antimony was not detected in onsite or runoff surface water samples).

5.1.2.1 Background. Antimony was detected in samples collected at two background locations, 2542 (dry season) and 2541 (wet season), at 20 $\mu\text{g/L}$ and 12.7 $\mu\text{g/L}$, (both below CRDL) respectively. Both of these concentrations are below AFWQC (see Table SW-6). Antimony was detected (15.9 $\mu\text{g/L}$ below CRDL) in one monthly runoff sample at Location 2500.

5.1.2.2 Onsite Sediment. Antimony was not detected in sediment samples collected during the transitional season. Antimony was detected in three samples collected during the dry season. Concentrations ranged from undetected to 8.2 mg/kg at Location 2515. Antimony was detected in most of the sediment samples collected during the wet season. Concentrations ranged from undetected to 33.9 mg/kg at Location 2530. Concentrations of antimony detected in onsite sediment samples collected for the three seasonal events are presented in Appendix SW-D. The range of antimony concentrations detected in onsite wet season sediment samples is greater than the range detected nationally (0.5-17.5 mg/kg; ATSDR 1990a).

5.1.3 Arsenic

Arsenic is a semi-metal or metalloid that generally occurs in concentrations below 10 $\mu\text{g/L}$ in stream waters. Concentrations above 50 $\mu\text{g/L}$ have been detected in stream waters, which were presumed to be the result of waste disposal (Hem 1989). In the vicinity of the STF site, arsenic has been detected at concentrations less than 10 $\mu\text{g/L}$, except in a sample collected from a heavy flow of a leachate/runoff seep from a catch basin in the Leach Creek area in January 1983 (Lum and Turney 1985). That concentration was 220 $\mu\text{g/L}$, which was several orders of magnitude higher than the other samples collected in the Leach Creek area. Lum and Turney (1985) reported concentrations of arsenic in sediment sampled in the Leach Creek area ranging from 6 mg/kg to 32 mg/kg.

5.1.3.1 Background. Arsenic was not detected in samples collected at any of the background locations during the dry season event (see Table SW-6). In background samples collected during the wet season event, arsenic was detected at concentrations below the CRDL at Locations 2500 (1.2 $\mu\text{g/L}$), 2540 (2.9 $\mu\text{g/L}$), and 2542 (3.6 $\mu\text{g/L}$). All reported arsenic concentrations for background samples were below AFWQC.

5.1.3.2 Runon. Arsenic was detected in a majority of the surface water runon samples at Locations 2500 and 2501. The monthly runon concentrations of arsenic ranged from undetected to 19.5 $\mu\text{g/L}$ at Location 2500 and ranged from undetected to 5.5 $\mu\text{g/L}$ (below CRDL) at Location 2501 (see Table SW-7). The stormwater runon concentrations of arsenic ranged from undetected to 6.3 $\mu\text{g/L}$ (below CRDL) at Location 2500 and from undetected to 25.2 $\mu\text{g/L}$ at Location 2501. Surface water runon concentrations did not exceed AFWQC for arsenic.

Generally, arsenic concentrations detected in stormwater runon samples were higher than those detected in monthly runon samples at both runon locations (see Appendix SW-B). The runon monthly and stormwater arsenic concentrations were slightly higher at Location 2501 than at Location 2500. Seasonal variations were

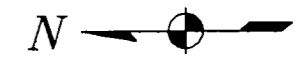
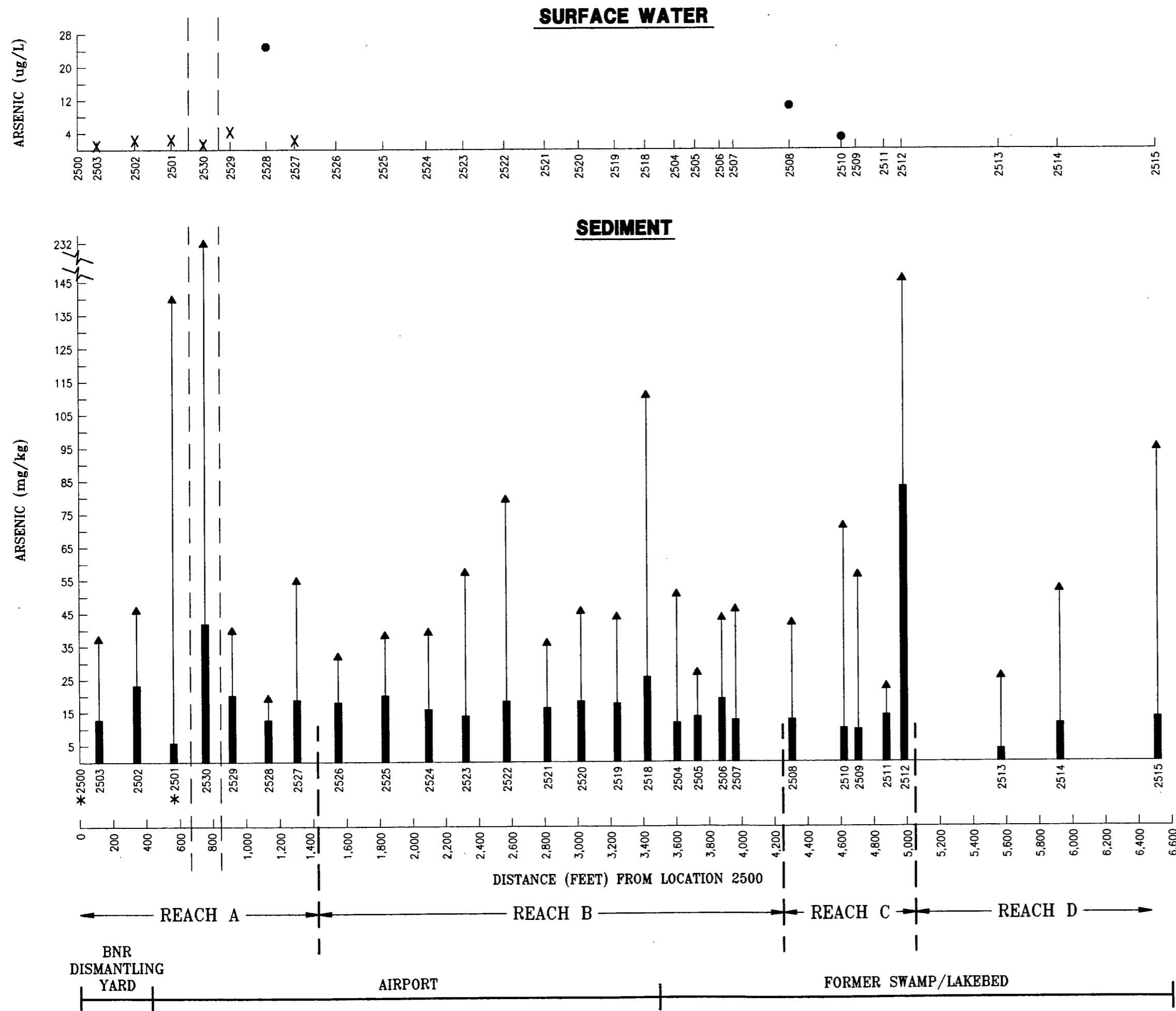
apparent with arsenic concentrations increasing during the months of June to October at both locations. The one exception includes the high concentrations of arsenic detected in the samples collected during the 100-year storm on 4 April 1991.

Monthly and stormwater runoff concentrations of arsenic exceeded the range of background arsenic concentrations at both runoff locations. However, the arsenic concentrations were below the concentrations detected nationally and within the range of concentrations detected in the Leach Creek area (Lum and Turney 1985).

5.1.3.3 Onsite Surface Water. Concentrations of arsenic in onsite surface water and sediment samples collected during the transitional season are presented in Appendix SW-D. Arsenic was detected at concentrations below the CRDL in onsite surface water samples collected from four locations during the transitional season. Concentrations ranged from undetected to 4.0 $\mu\text{g/L}$ at Location 2516 (see Table SW-8). No onsite concentrations exceeded the maximum runoff surface water concentration of 25.2 $\mu\text{g/L}$. Transitional season surface water concentrations did not exceed the AFWQC for arsenic (1,210 $\mu\text{g/L}$) at any location.

Concentrations of arsenic in onsite surface water and sediment samples collected during the dry season are presented in Appendix SW-D and Figure SW-10. Concentrations in onsite surface water samples ranged from undetected to 24.8 $\mu\text{g/L}$ at Location 2528 in Reach A. Detected concentrations did not exceed the maximum runoff surface water concentration of 25.2 $\mu\text{g/L}$. Dry season surface water concentrations did not exceed AFWQC for arsenic at any location.

Concentrations of arsenic in onsite surface water and sediment samples collected during the wet season are presented in Appendix SW-D and Figure SW-11. Wet season surface water concentrations ranged from undetected to 8.0 $\mu\text{g/L}$ (all detected concentrations below CRDL) at Location 2521. The most elevated concentrations were detected in samples collected from the central section of Reach B. Arsenic concentrations then declined to relatively low levels in the



LEGEND

- SURFACE WATER CONCENTRATION
- DRY-WEIGHT NORMALIZATION
- ▲ FINE-GRAIN NORMALIZATION
- X 1/2 DETECTION LIMIT
- * SURFACE WATER RUNON LOCATION

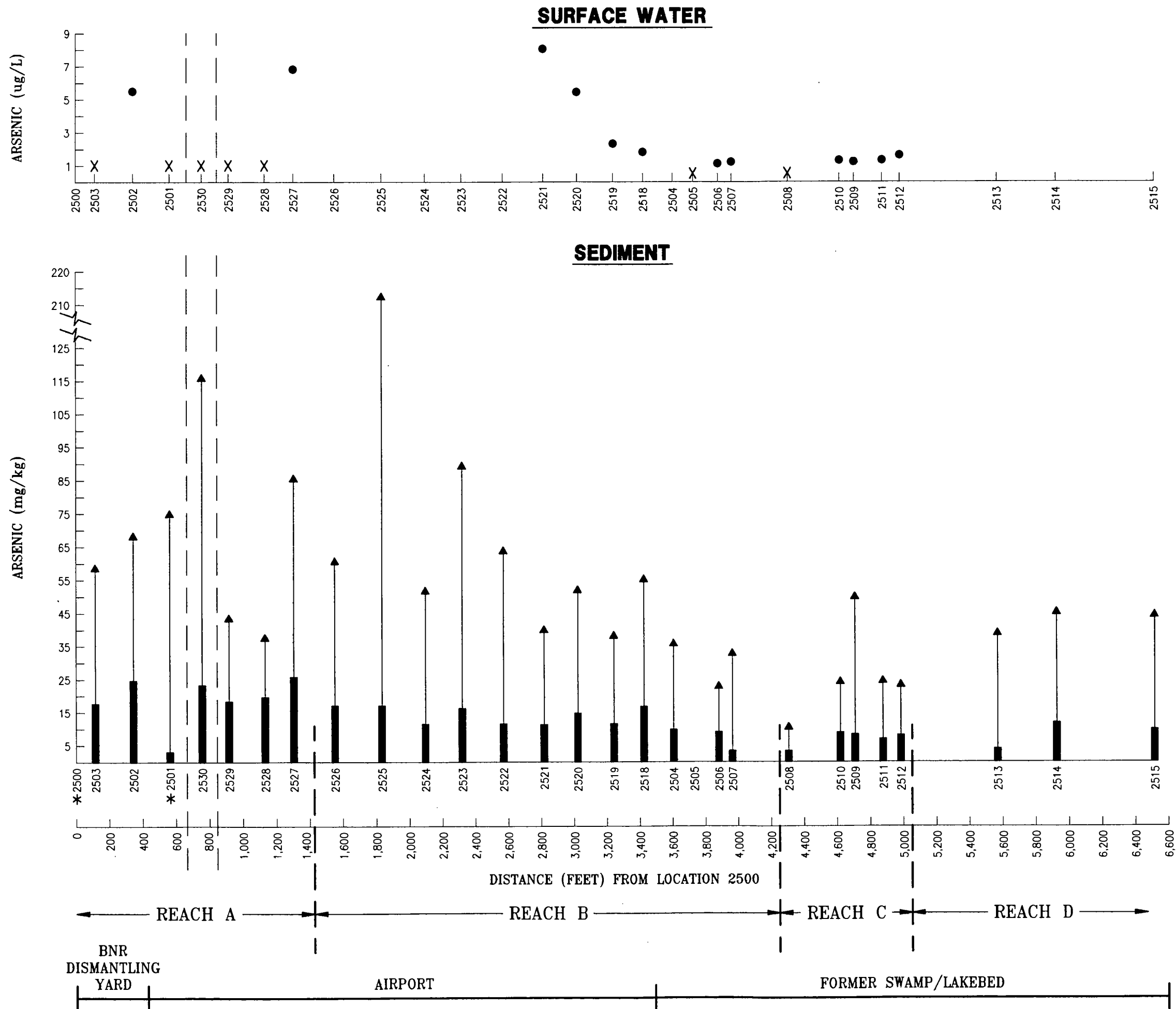
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SOUTH TACOMA FIELD
TACOMA, WA

**ARSENIC CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (DRY SEASON, AUGUST 1991)**

916055.24/P2SK013

FIGURE SW-10



LEGEND

- SURFACE WATER CONCENTRATION
- DRY-WEIGHT NORMALIZATION
- ▲ FINE-GRAIN NORMALIZATION
- X 1/2 DETECTION LIMIT
- * SURFACE WATER RUNON LOCATION

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SOUTH TACOMA FIELD
TACOMA, WA

**ARSENIC CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (WET SEASON, JANUARY 1992)**

916055.24/P2SK036

FIGURE SW-11

southern section of Reach B and in Reach C. No onsite surface water concentrations exceeded the maximum runoff surface water concentration for arsenic. Wet season surface water concentrations did not exceed AFWQC at any location.

All arsenic concentrations detected in onsite surface water were below concentrations detected in U.S. stream waters ($10 \mu\text{g/L}$; Hem 1989), except for two concentrations detected in samples collected during the dry season. However, those concentrations were below $50 \mu\text{g/L}$, which Hem (1985) reported as a concentration that was presumably the result of waste disposal. All arsenic concentrations for onsite surface water were similar to concentrations detected in the Leach Creek area (Lum and Turney 1985). Maximum surface water concentrations detected in the dry season sample were approximately three to six times greater than concentrations detected in the wet and transitional season samples.

5.1.3.4 Onsite Sediment. Arsenic was detected in all onsite sediment samples collected during the transitional season. Concentrations ranged from 0.71 mg/kg (below CRDL) at Location 2516 to 93.8 mg/kg at Location 2506.

Arsenic was detected in onsite sediment samples collected from all locations during the dry season. Concentrations ranged from 2.3 mg/kg at Location 2516 to 83.1 mg/kg at Location 2512. Generally, dry weight concentrations were relatively constant over the length of the surface water channel and were below 25 mg/kg , except for samples collected from Location 2530 (41.8 mg/kg) and Location 2512 (83.1 mg/kg). When normalized to percent fine-grain material, the maximum arsenic concentrations were detected at Locations 2501 and 2530 in Reach A, where percentages of fine-grain material were low (4 and 18 percent, respectively). In the southern section of Reach A and in all of Reach B, the amount of fine-grain material was generally between 23 and 65 percent. In Reaches A and B, the normalized concentrations do not appear to follow any trends.

In Reach C, the percent fine-grain material is relatively low in the northern locations and high in the southern locations. The normalized concentrations generally increase from the northern locations to the southern locations, except at Location 2511. Reach D shows a similar trend (i.e., the normalized concentrations increase from the north to the south).

Arsenic was detected in all onsite sediment samples collected during the wet season. Concentrations ranged from 1.4 mg/kg (below CRDL) at Location 2516 to 25.7 mg/kg at Location 2527. Dry weight concentrations were relatively higher in Reach A and the northern section of Reach B compared to the southern section of Reach B and Reaches C and D. When normalized to percent fine-grain material, concentrations were relatively high in Reach A and the northern section of Reach B compared to other sample locations. Normalized concentrations decreased through the remainder of Reach B and then increased in Reaches C and D.

Maximum sediment concentrations of arsenic were approximately three to four times greater in samples collected during the transitional and dry seasons compared to the wet season. In addition, the range of arsenic concentrations detected in onsite sediment samples collected during the transitional and dry season events are greater than the concentrations (6-32 mg/kg) reported by USGS (Lum and Turney 1985).

5.1.3.5 Runoff. Arsenic was detected below the CRDL in three of four biweekly surface water runoff samples and the one storm runoff sample collected at Location 2515. The biweekly runoff surface water concentrations ranged from undetected to 4.0 $\mu\text{g/L}$ (see Table SW-9). The stormwater runoff concentration was 1.4 $\mu\text{g/L}$. All of the detected concentrations were below the AFWQC. In addition, all runoff concentrations were within the range of runoff concentrations and within concentration ranges detected in stream water and the Leach Creek area (Lum and Turney 1985).

5.1.4 Barium

Barium is a naturally occurring alkaline earth metal. It is relatively abundant in the Earth's crust and is detected in almost all surface water at concentrations less than 380 $\mu\text{g/L}$. Sedimentation of suspended solids removes a large portion of barium content from surface water (ATSDR 1990b).

5.1.4.1 Background. Barium was detected below the CRDL in background samples collected during the dry season event at Locations 2540 (25.9 $\mu\text{g/L}$), 2541 (20.8 $\mu\text{g/L}$), and 2543 (28 $\mu\text{g/L}$) (see Table SW-6). Barium was detected below the CRDL in samples collected at all background locations during the wet season event, except at Location 2500 where barium was undetected. Barium concentrations for wet season samples ranged from undetected to 26.9 $\mu\text{g/L}$. No WQC have been proposed by EPA for barium. Seasonal variations in detected barium concentrations for background samples appear to be minimal.

5.1.4.2 Runon. Barium was detected in all runon samples collected except two monthly samples collected at Location 2500. Monthly runon concentrations ranged from undetected to 25.6 $\mu\text{g/L}$ (all below CRDL) at Location 2500 and from 13.9 $\mu\text{g/L}$ to 176 $\mu\text{g/L}$ at Location 2501 (see Table SW-7). Stormwater runon concentrations of barium ranged from 10.2 $\mu\text{g/L}$ to 48.3 $\mu\text{g/L}$ at Location 2500 and ranged from 52.9 $\mu\text{g/L}$ (below CRDL) to 252 $\mu\text{g/L}$ at Location 2501.

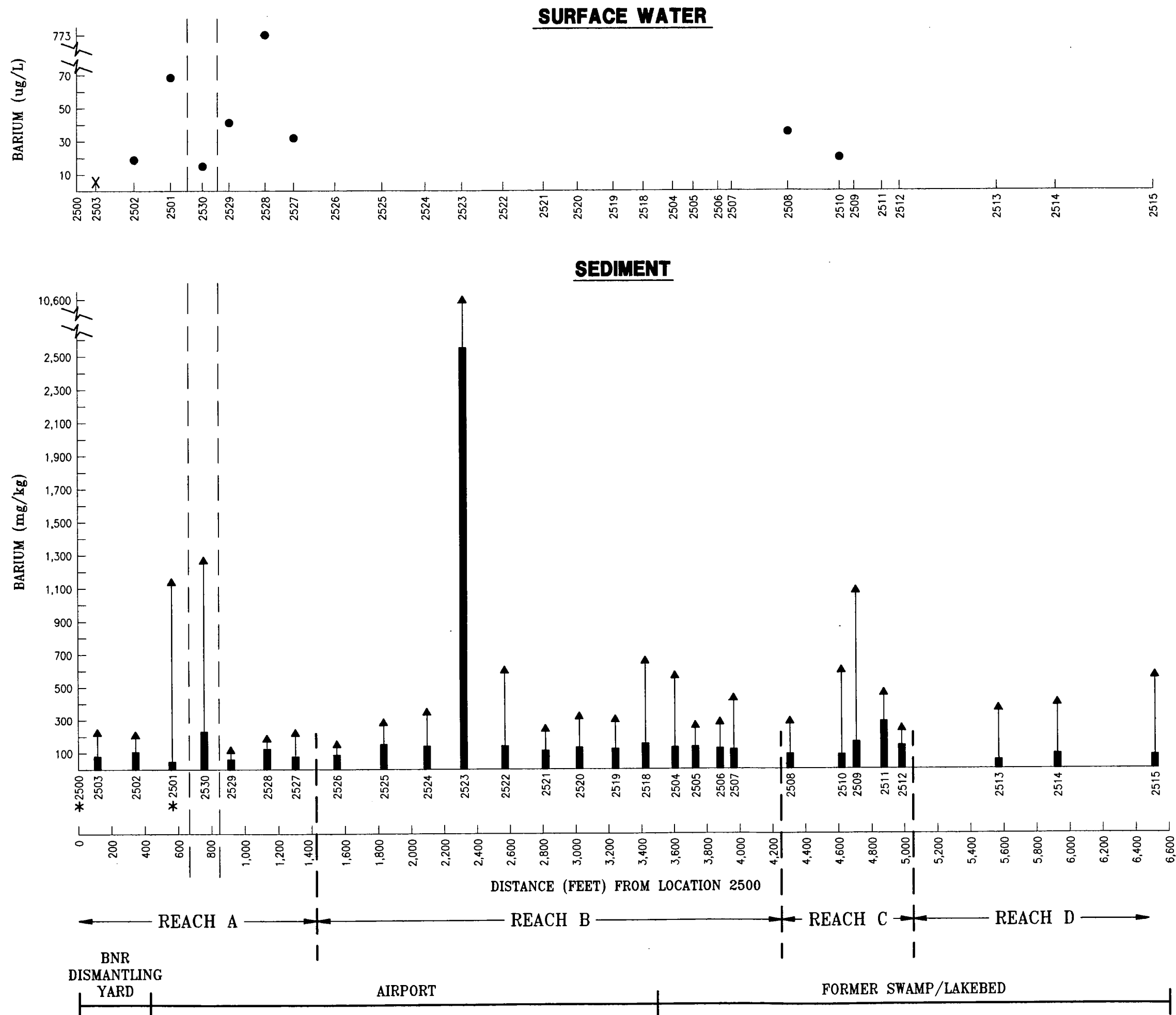
Generally, barium concentrations detected in stormwater runon samples were higher than those detected in monthly samples runon at both runon locations (see Appendix SW-B). The runon monthly and stormwater concentrations detected in samples collected at Location 2501 were greater than those detected in samples collected at Location 2500. Seasonal variations were apparent with barium concentrations increasing during the months of June to October at Location 2500 and through November at Location 2501. The one exception includes the high concentrations of barium detected in the samples collected during the 100-year storm on 4 April 1991 at both locations.

Concentrations of barium exceeded the range of background surface water concentrations in over 50 percent of the monthly runoff samples at Location 2501. One-third of the detected concentrations for runoff storm event samples collected at Location 2500 and all of the detected concentrations for runoff storm event samples collected at Location 2501 exceeded the background surface water concentration ranges. All barium concentrations detected in monthly surface water and stormwater runoff samples were below the maximum concentration ($380 \mu\text{g/L}$) reported by ATSDR (1990b) for surface water samples.

5.1.4.3 Onsite Surface Water. Concentrations of barium in onsite surface water and sediment samples collected during the transitional season are presented in Appendix SW-D. Barium was detected at concentrations below the CRDL in all transitional surface water samples. Concentrations ranged from $11.0 \mu\text{g/L}$ at Location 2511 to $37.5 \mu\text{g/L}$ at Location 2509 (see Table SW-8). No WQC exists for barium.

Concentrations of barium in onsite surface water and sediment samples collected during the dry season are presented in Appendix SW-D and Figure SW-12. Barium concentrations in surface water samples ranged from undetected to $773 \mu\text{g/L}$ at Location 2528. All detected concentrations, except for the maximum concentration, were below the CRDL. Most detected concentrations were associated with samples collected from Reach A. Only the concentration associated with the sample collected from Location 2528 exceeded the maximum runoff surface water concentration of $252 \mu\text{g/L}$.

Concentrations of barium in onsite surface water and sediment samples collected during the wet season are presented in Appendix SW-D and Figure SW-13. Concentrations in surface water samples ranged from $9.9 \mu\text{g/L}$ at Location 2506 to $43.5 \mu\text{g/L}$ at Location 2527. All detected concentrations were below the CRDL. Concentrations were relatively constant in Reach A (except at Location 2501) and the northern section of Reach B. However, the most elevated concentration was detected in the northern section of Reach B. Concentrations declined steadily in the



LEGEND

- SURFACE WATER CONCENTRATION
- DRY-WEIGHT NORMALIZATION
- ▲ FINE-GRAIN NORMALIZATION
- X 1/2 DETECTION LIMIT
- * SURFACE WATER RUNON LOCATION

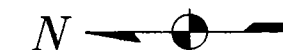
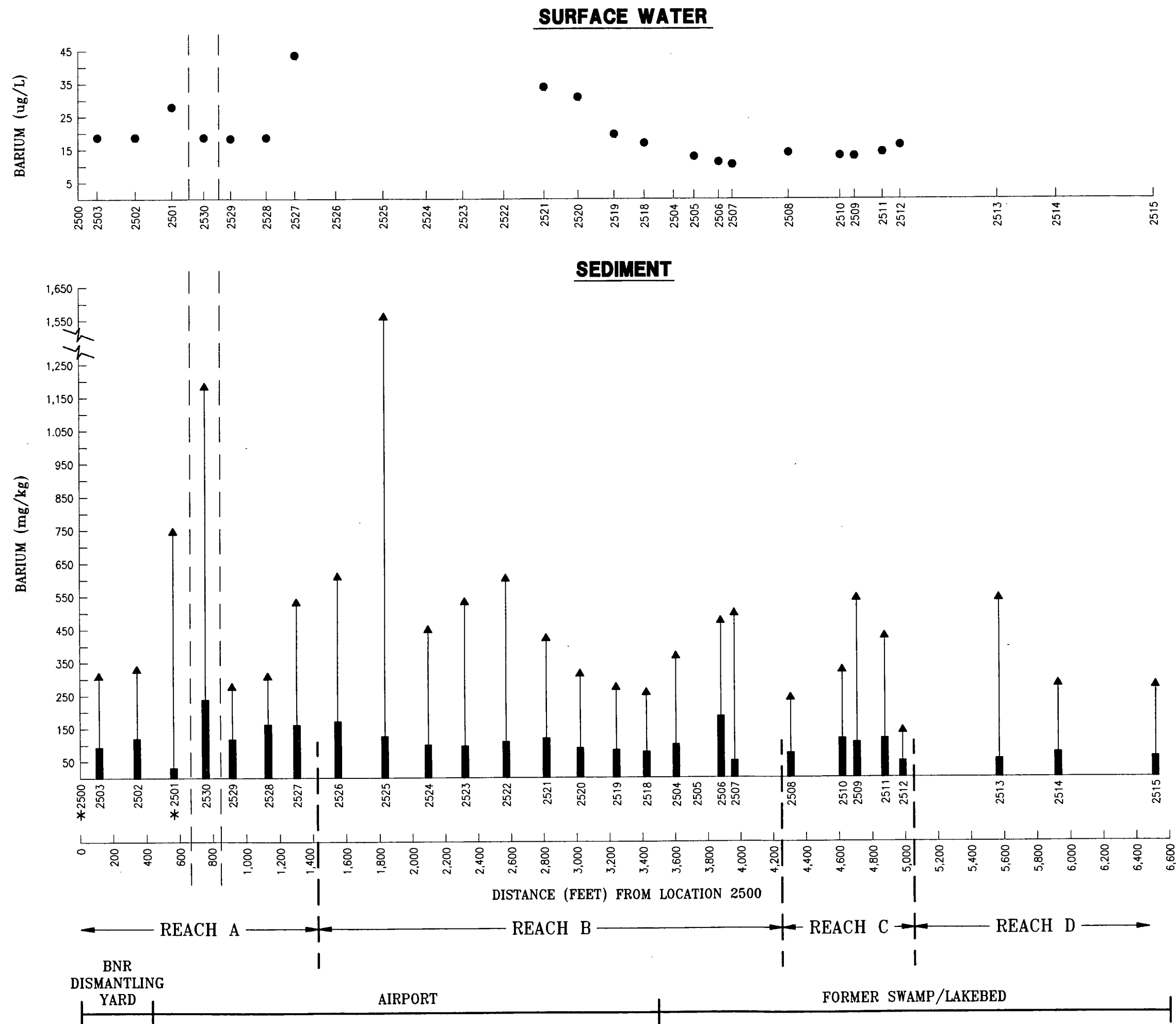
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**BARIUM CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (DRY SEASON, AUGUST 1991)**

916055.24/P2SK014

FIGURE SW-12



LEGEND

- SURFACE WATER CONCENTRATION
- DRY-WEIGHT NORMALIZATION
- ▲ FINE-GRAIN NORMALIZATION
- X 1/2 DETECTION LIMIT
- * SURFACE WATER RUNON LOCATION

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TACOMA, WA

**BARIUM CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (WET SEASON, JANUARY 1992)**

916055.24/P2SK037

FIGURE SW-13

remainder of Reach B before increasing gradually in Reach C. Detected barium concentration for wet season samples did not exceed the maximum runoff surface water concentration.

The maximum barium concentration was more than one order of magnitude greater in the dry season samples compared to the wet and transitional season samples. Generally, barium concentrations for all onsite surface water samples were typical of those reported by ATSDR (1990b). However, barium was detected in a sample collected from Location 2528 at a concentration (773 $\mu\text{g/L}$) that exceeded the maximum concentration (380 $\mu\text{g/L}$) reported by ATSDR (1990b).

5.1.4.4 Onsite Sediment. Barium was detected in all onsite sediment samples collected during the transitional season. Concentrations ranged from 31.4 mg/kg at Location 2516 to 153 mg/kg at Location 2511.

Barium was detected in all onsite sediment samples collected during the dry season. Concentrations ranged from 28.0 mg/kg (below CRDL) at Location 2516 to 2,550 mg/kg at Location 2523. Generally, dry weight concentrations were below 250 mg/kg except for two samples collected at Locations 2511 and 2523. Barium concentrations were fairly uniform in all reaches except for the two most elevated concentrations in Reaches B and C. When normalized to percent fine-grain material, most concentrations were below 600 mg/kg, except at Locations 2501, 2530, and 2523. As noted for aluminum and arsenic, the percent of fine-grain material at Locations 2501 and 2530 is low (4 and 18 percent, respectively) relative to other locations, accounting for the higher normalized concentrations. Typically, sample locations with relatively low amounts of fine-grain material exhibited higher normalized concentrations. No trends are apparent, except possibly in Reach D, where normalized concentrations increased from northern to southern locations.

Barium was detected in all onsite sediment samples collected during the wet season. Concentrations ranged from 29.9 mg/kg (below CRDL) at Location 2501 to 237 mg/kg at Location 2530. Dry weight concentrations were generally higher

in Reach A and the northern section of Reach B. Concentrations then declined gradually and leveled off in the southern section of Reach B and in Reaches C and D. A deviation from this trend was at Location 2506 where the dry weight concentration increased from 100 mg/kg at Location 2504 to 186 mg/kg at Location 2506 before declining to 50 mg/kg at Location 2507.

When normalized to percent fine-grain material, barium concentrations were relatively high in Reach A and in the northern section of Reach B. Higher concentrations were generally noted when the percent of fine-grain material was low and the dry weight concentrations were elevated. The most elevated normalized concentration was reported for the sample collected from Location 2525, where fine-grain material was only 8 percent. Normalized concentrations then declined and remained in a range of approximately 130 mg/kg to 600 mg/kg for the remainder of Reach B and all of Reaches C and D.

The maximum dry season barium concentration was approximately one order of magnitude greater in the sediment samples compared to the wet and transitional season samples.

5.1.4.5 Runoff. Barium was detected in all runoff biweekly surface water and stormwater samples collected from Location 2515. Biweekly surface water runoff concentrations ranged from 15.7 $\mu\text{g/L}$ to 31.2 $\mu\text{g/L}$ (all below CRDL). The stormwater runoff concentration was 16.8 $\mu\text{g/L}$ (below CRDL). Runoff concentrations were within the range of runoff concentrations and below the maximum concentration (380 $\mu\text{g/L}$) reported by ATSDR (1990b), except for one biweekly surface water runoff concentration which was greater than the runoff concentrations detected at Location 2500.

5.1.5 Beryllium

The concentrations of beryllium in a variety of environmental surface waters are generally below 1 $\mu\text{g/L}$. Beryllium is a relatively rare component. It is likely that in most natural waters, beryllium is present in the particulate form. The average concentration range in the Earth's crust is 2.8-5.0 $\mu\text{g/g}$ (ATSDR 1987e).

5.1.5.1 Onsite Surface Water. Beryllium was only detected in one onsite surface water sample collected during the three sampling events (i.e., beryllium was not detected in background, runoff, or runoff surface water samples). Beryllium was detected at 1.9 $\mu\text{g/L}$ (below CRDL) in the sample collected during the dry season from Location 2528.

5.1.5.2 Onsite Sediment. Beryllium was not detected in sediment samples collected during the transitional season. Beryllium was detected in 14 sediment samples collected during the dry season. Concentrations ranged from undetected to 1.1 mg/kg at Location 2530. Detected concentrations were all below the CRDL. During the wet season event, beryllium was detected only in the sample collected from Location 2530 at a reported concentration of 0.55 mg/kg (below CRDL). Detected beryllium concentrations for all seasonal sampling events are presented in Appendix SW-D.

5.1.6 Boron

Boron, a naturally occurring nonvolatile metalloid, is widely distributed in surface water with an average concentration of 0.1 mg/L for the U.S. Boron is found mainly as an inorganic compound in sediments. Water-borne boron may be adsorbed by sediments or co-precipitated with aluminum, silicon, or iron to form hydroxyborate compounds on the surfaces of minerals (ATSDR 1990d).

5.1.6.1 Background. In background samples collected during the dry season event, boron was detected below the CRDL at Locations 2541 (66.3 $\mu\text{g/L}$), 2543 (38.6 $\mu\text{g/L}$), and 2543 (36.1 $\mu\text{g/L}$). In background samples collected during the wet season event, boron was detected below the CRDL at Location 2500 (36.1 $\mu\text{g/L}$). WQC for boron have not been proposed by EPA. Boron was detected more frequently and at higher concentrations in samples collected during the dry season than the wet season.

6.1.6.2 Runon. Boron was detected in monthly runon samples at concentrations ranging from undetected to 46.9 $\mu\text{g/L}$ at Location 2500 and ranging from undetected to 174.4 $\mu\text{g/L}$ at Location 2501. Stormwater runon concentrations ranged from undetected to 36.4 $\mu\text{g/L}$ at Location 2500 and ranged from undetected to 102 $\mu\text{g/L}$ at Location 2501.

All concentrations of boron detected at both runon locations were within the range of background concentrations except for one of the monthly runon samples and one of the stormwater runon samples collected at Location 2501. Boron concentrations detected in the runon samples were within the reported average for surface waters of the U.S. (0.1 mg/L) (ATSDR 1990d).

5.1.6.3 Onsite Surface Water. Boron was not analyzed in onsite surface water samples collected during the transitional season. Boron was detected in six samples collected during the dry season at concentrations ranging from undetected to 34.6 $\mu\text{g/L}$ at Location 2528 (see Table SW-8). Boron was detected in most onsite surface water samples collected during the wet season. Those concentrations ranged from undetected to 47.4 $\mu\text{g/L}$ at Location 2509.

Boron concentrations in onsite surface water samples were within the range of detected concentrations for the monthly runon sample. However, the dry season onsite range of concentrations were higher than the stormwater runon concentration range. All of the detected onsite concentrations were below the average concentration (0.1 mg/L) for U.S. surface waters (ATSDR 1987f).

5.1.6.4 Onsite Sediment. Boron was not analyzed in onsite sediment samples collected during the transitional season. Boron was not detected in sediment samples collected during the dry season and detected in only three sediment samples collected during the wet season. Concentrations of 47.6 mg/kg, 7.8 mg/kg (below CRDL), and 13.6 mg/kg (below CRDL) were reported for samples collected from Locations 2502, 2525, and 2530, respectively. Detected concentrations of boron for all sampling events are presented in Appendix SW-D.

5.1.6.5 Runoff. Boron was detected in surface water samples collected at runoff Location 2515. The biweekly surface water runoff concentration ranged from undetected to 39.8 $\mu\text{g/L}$ (below CRDL). The stormwater runoff concentration was undetected. Runoff concentrations were within the range of runoff concentrations and below the average U.S. surface water concentration of 0.1 mg/L.

5.1.7 Cadmium

Cadmium enters the environment to a limited extent from natural weathering of minerals (ATSDR 1987f). The median concentration of cadmium in U.S. surface waters is 1 $\mu\text{g/L}$ (Hem 1989). Significant sources of cadmium are anthropogenic. Cadmium sorption by clays, iron oxides, and precipitation as cadmium sulfide will reduce the aquatic load of cadmium (ATSDR 1987f). Cadmium concentrations were less than 0.5 $\mu\text{g/L}$ in surface water samples collected in the Leach Creek area in January 1983. Cadmium concentrations ranging from 0.5 to 3.1 mg/kg have been detected in sediment samples collected in the Leach Creek area (Lum and Turney 1985).

5.1.7.1 Runon. Cadmium was undetected in all background, runoff, onsite, runoff surface water samples, except one surface water runoff sample and one onsite surface water sample. The cadmium concentration in the monthly runoff sample was detected at 2.4 $\mu\text{g/L}$ (below CRDL) at Location 2501 (see Table SW-7), which exceeded the 1-hour average WQC of 1.7 $\mu\text{g/L}$.

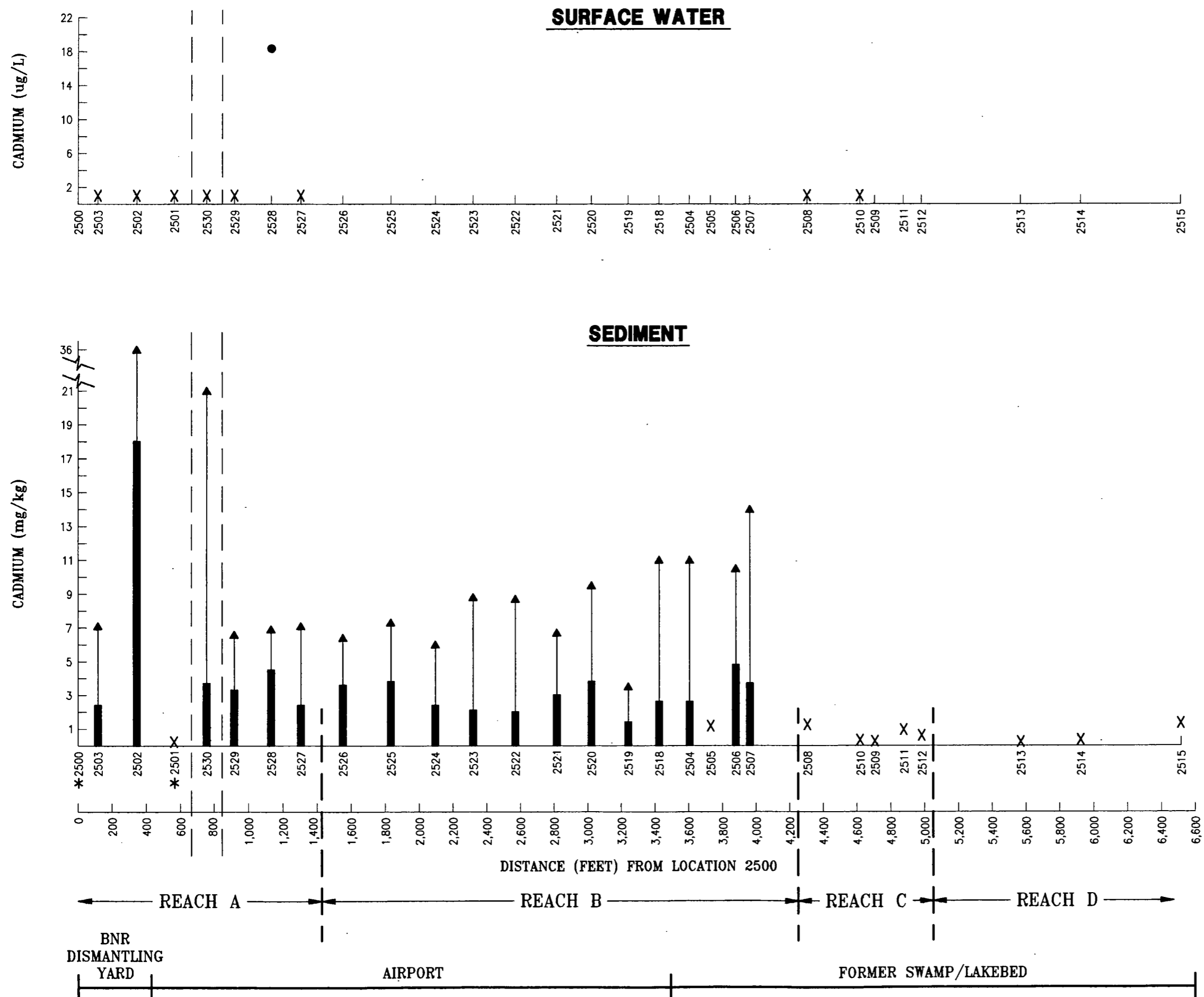
The detected concentration of 2.4 $\mu\text{g/L}$ also exceeded the background surface water range, the median concentration of 1 $\mu\text{g/L}$ for surface waters, and the concentration range for samples collected in the vicinity of STF in the Leach Creek area (Lum and Turney 1985).

5.1.7.2 Onsite Surface Water. Concentrations of cadmium in onsite surface water and sediment samples collected during the dry and wet seasons are presented in Appendix SW-D and Figures SW-14 and SW-15. Concentrations were undetected in all surface water samples except the sample collected during the dry season from Location 2528. That concentration of 18.3 $\mu\text{g/L}$ exceeded the maximum runon surface water concentration which was detected at 3.0 $\mu\text{g/L}$, the AFWQC for cadmium of 2.67 $\mu\text{g/L}$, the median concentration of 1 $\mu\text{g/L}$ for surface water, and the concentration range for samples collected in the vicinity of STF in the Leach Creek area (Lum and Turney 1895).

5.1.7.3 Onsite Sediment. Cadmium was detected in two of the five sediment samples collected during the transitional season. Concentrations ranged from undetected to 6.7 mg/kg at Location 2506.

Cadmium was detected in 18 of 33 sediment samples collected during the dry season. Concentrations ranged from undetected to 18.0 mg/kg at Location 2502. Most concentrations were detected below 5 mg/kg, in Reaches A and B except at Location 2502. Concentrations in Reaches C and D were all undetected. When normalized to percent fine-grain material, cadmium concentrations generally did not exhibit the range in concentrations as shown for arsenic and, to a lesser extent, for barium. The exception to this generalization was in Reach A, where the low quantity of fine-grain material resulted in a high normalized concentration for Location 2530.

Cadmium was detected in 17 of 31 sediment samples collected during the wet season. Concentrations ranged from undetected to 10.8 mg/kg at Location 2506. Cadmium concentrations (dry weight basis) were the most elevated in Reach A and



LEGEND

- SURFACE WATER CONCENTRATION
- DRY-WEIGHT NORMALIZATION
- ▲ FINE-GRAIN NORMALIZATION
- X 1/2 DETECTION LIMIT
- * SURFACE WATER RUNON LOCATION

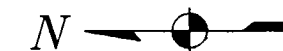
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TACOMA, WA

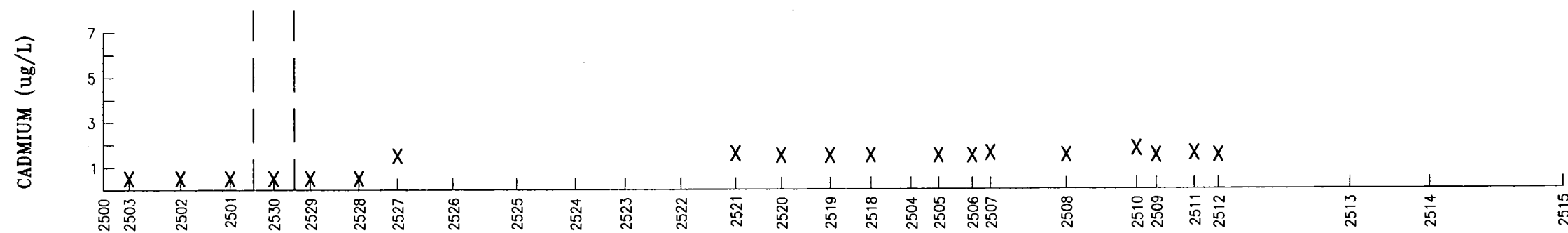
**CADMIUM CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (DRY SEASON, AUGUST 1991)**

916055.24/P2SK015

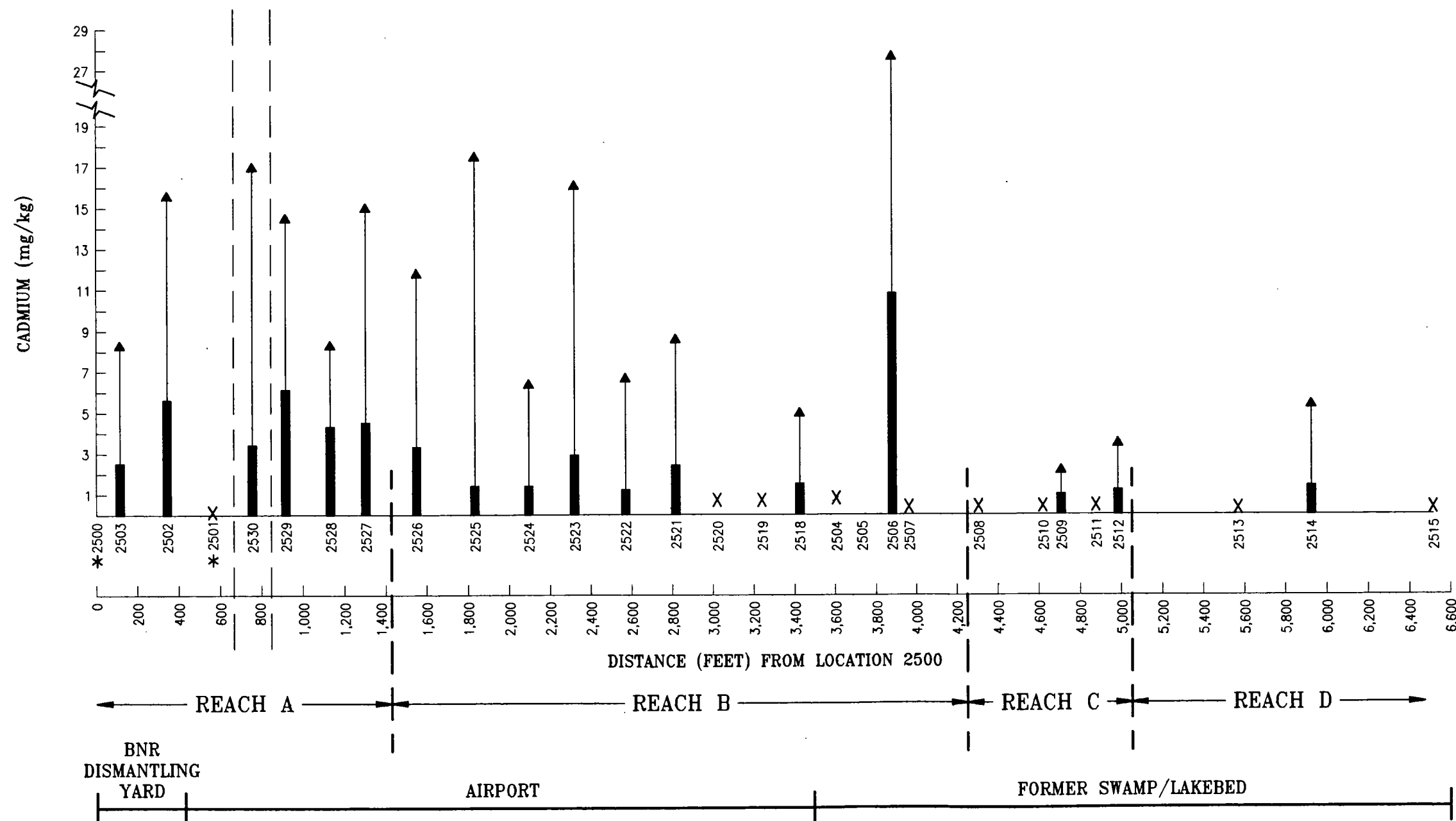
FIGURE SW-14



SURFACE WATER



SEDIMENT



LEGEND

- SURFACE WATER CONCENTRATION
- DRY-WEIGHT NORMALIZATION
- ▲ FINE-GRAIN NORMALIZATION
- X 1/2 DETECTION LIMIT
- * SURFACE WATER RUNON LOCATION

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**CADMIUM CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (WET SEASON, JANUARY 1992)**

916055.24/P2SK038

FIGURE SW-15

fairly uniform in the remaining reaches. When normalized to percent fine-grain material, the most elevated concentration was associated with Location 2506 where the maximum dry weight concentration was reported. Except for this deviation, normalized concentrations appeared to be decreasing from Reach A and the northern section of Reach B to the southern section of Reach B and Reaches C and D.

Maximum sediment cadmium concentrations did not vary considerably among the three sampling seasons, and all exceeded sediment concentrations detected in the Leach Creek area (Lum and Turney 1985).

5.1.8 Calcium

Calcium is an alkaline earth metal and is a major component of solutes that are naturally occurring in surface waters. Calcium tends to precipitates as calcium carbonate when water is impounded (Hem 1989).

5.1.8.1 Background. Calcium was detected in surface water samples collected at all background locations in concentrations that ranged from 5,900 $\mu\text{g/L}$ to 79,600 $\mu\text{g/L}$ for the dry season event and from 4240 $\mu\text{g/L}$ (below CRDL) to 76,700 $\mu\text{g/L}$ for the wet season event (see Table SW-6). WQC have not been proposed by the EPA for calcium. The seasonal variation of detected calcium concentrations appears to be minimal.

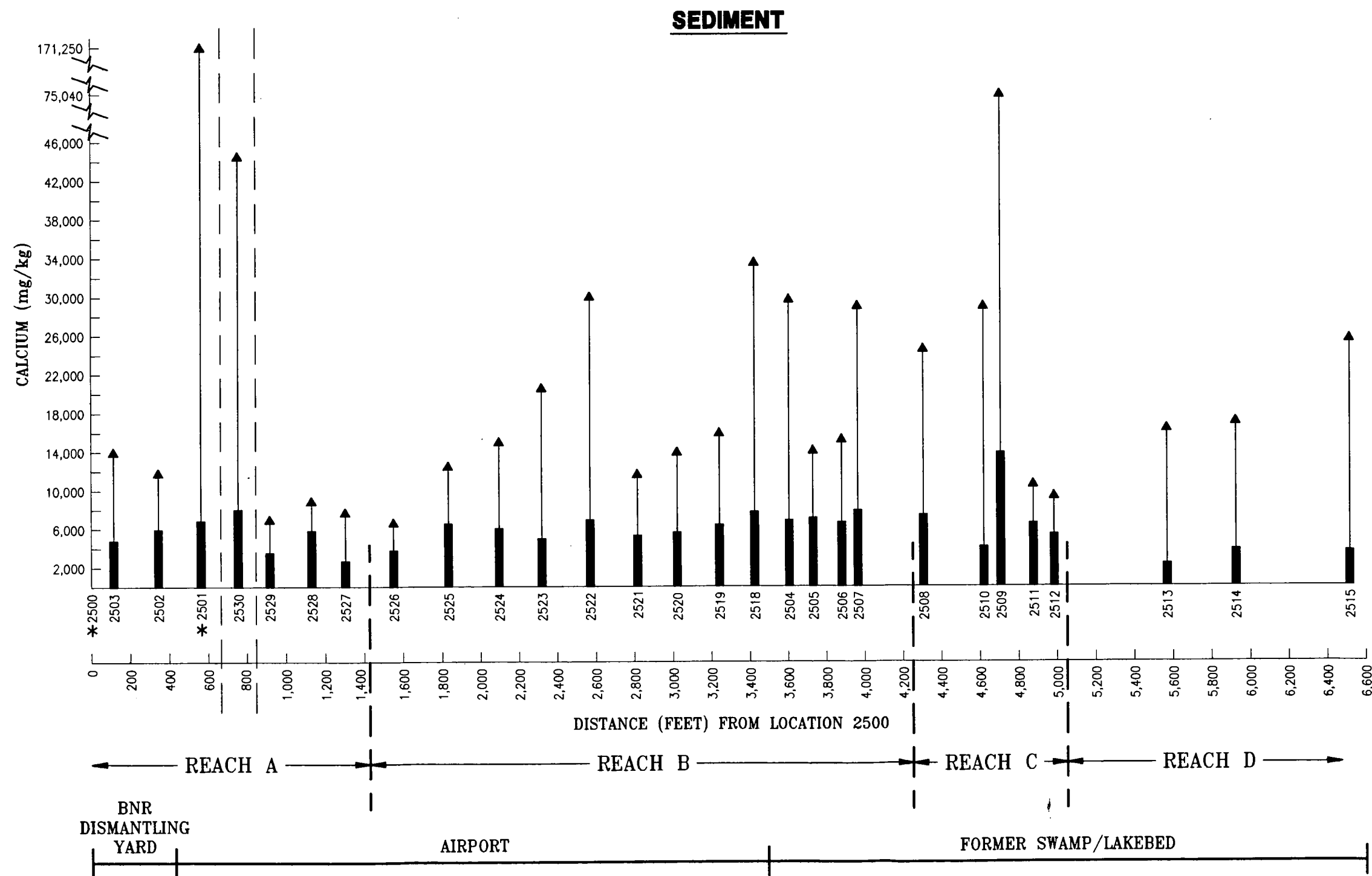
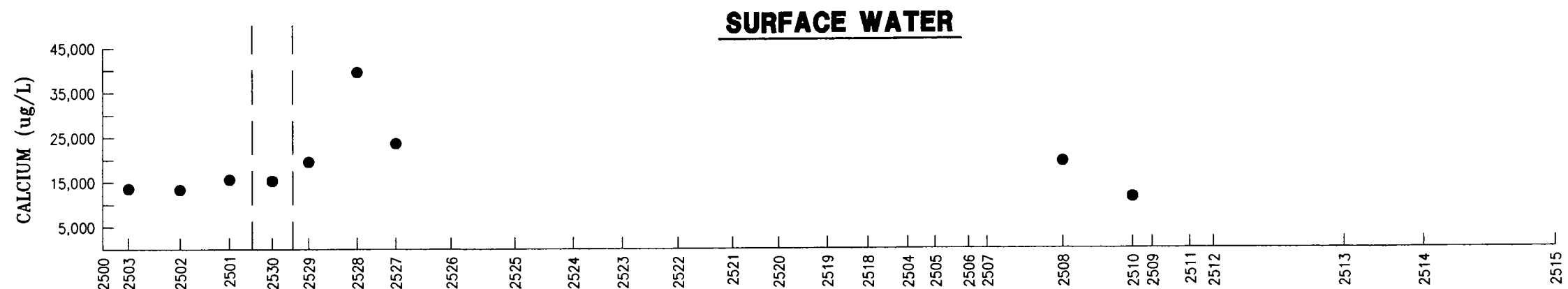
5.1.8.2 Runon. Calcium was detected in all surface water runon samples collected at both locations. Monthly surface water runon concentrations of calcium ranged from 6,510 $\mu\text{g/L}$ to 21,900 $\mu\text{g/L}$ at Location 2500 and from 3,870 $\mu\text{g/L}$ to 16,300 $\mu\text{g/L}$ at Location 2501 (see Table SW-7). Stormwater runon concentrations of calcium ranged from 2,500 $\mu\text{g/L}$ to 8,030 $\mu\text{g/L}$ at Location 2500 and from 3,980 $\mu\text{g/L}$ to 15,900 $\mu\text{g/L}$ at Location 2501.

The calcium concentrations were detected at higher concentrations in the monthly runon samples than the stormwater runon samples collected at Location 2500. However, at Location 2501 the stormwater concentrations were similar to the monthly runon concentrations. Samples collected at Location 2500 had monthly runon concentrations that were higher than those detected in samples collected from Location 2501. Stormwater samples collected at Location 2500 had lower concentrations than those detected at Location 2501. Calcium concentrations for surface water runon samples were within or below the range of concentrations detected in background surface water.

5.1.8.3 Onsite Surface Water. Concentrations of calcium in onsite surface water and sediment samples collected during the transitional season are presented in Appendix SW-D. Calcium was detected in all onsite (transitional season) surface water samples. Concentrations ranged from 6,460 $\mu\text{g/L}$ at Location 2511 to 59,300 $\mu\text{g/L}$ at Location 2516 (see Table SW-8). The concentrations associated with the two samples collected from Location 2516 exceeded the maximum surface water runon concentration of 21,900 $\mu\text{g/L}$.

Concentrations of calcium in onsite surface water and sediment samples collected during the dry season are presented in Appendix SW-D and Figure SW-16. Calcium was detected in all onsite (dry season) surface water samples. Concentrations ranged from 11,400 $\mu\text{g/L}$ at Location 2510 to 39,500 $\mu\text{g/L}$ at Location 2528. Concentrations associated with the samples collected from Locations 2527 and 2528 exceeded the maximum runon surface water concentration.

Concentrations of calcium in onsite surface water and sediment samples collected during the wet season are presented in Appendix SW-D and Figure SW-17. Calcium was detected in all onsite (wet season) surface water samples. Concentrations ranged from 4,960 $\mu\text{g/L}$ (below CRDL) at Location 2502 to 14,600 at Location 2527. Concentrations appeared to increase from Reach A to the northern section of Reach B, gradually decrease in the southern section of Reach B



LEGEND

- SURFACE WATER CONCENTRATION
- DRY-WEIGHT NORMALIZATION
- ▲ FINE-GRAIN NORMALIZATION
- X 1/2 DETECTION LIMIT
- * SURFACE WATER RUNON LOCATION

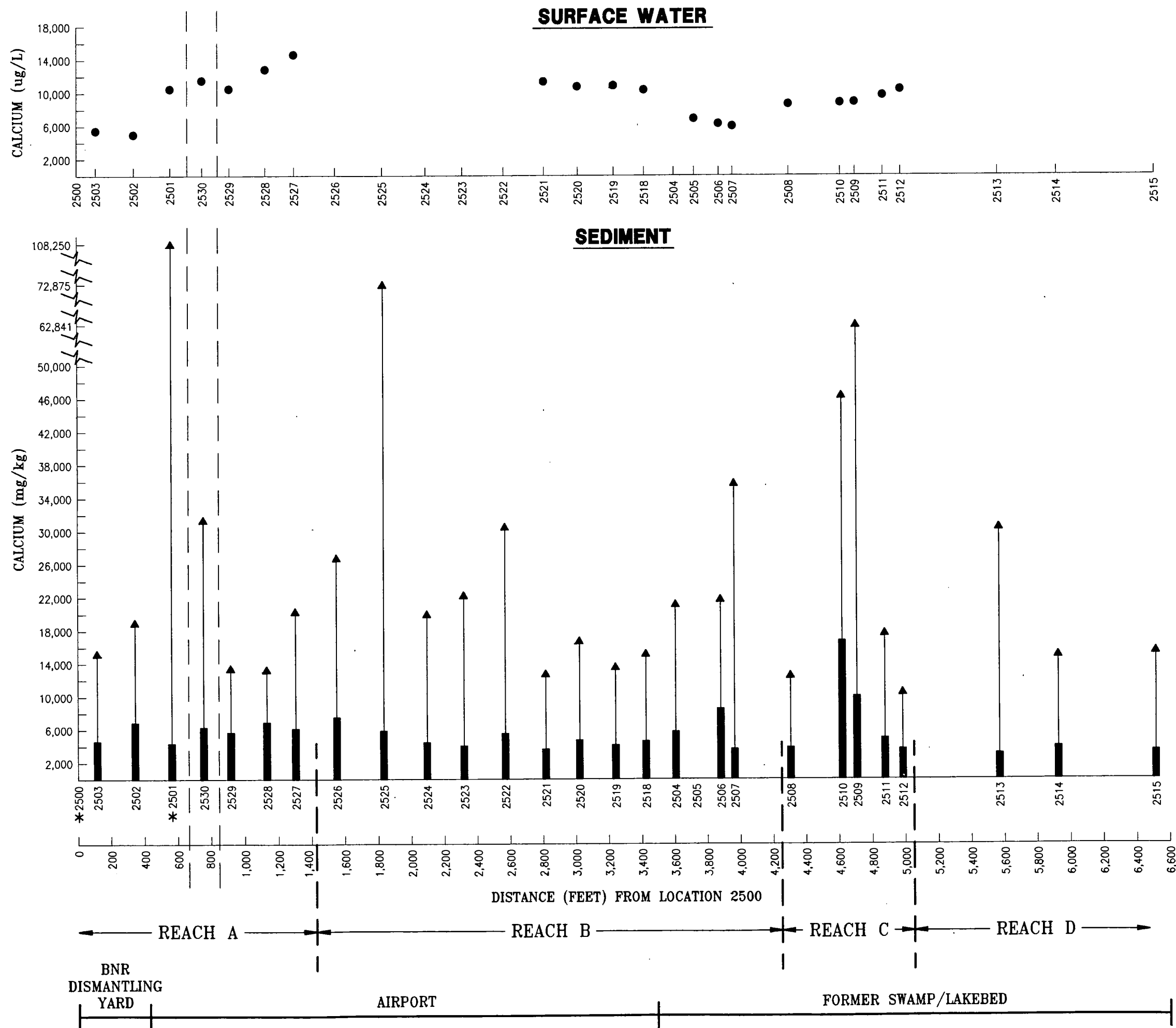
Kennedy/Jenks Consultants

SOUTH TACOMA FIELD
TACOMA, WA

**CALCIUM CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (DRY SEASON, AUGUST 1991)**

916055.24/P2SK053

FIGURE SW-16



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SOUTH TACOMA FIELD
TACOMA, WA

**CALCIUM CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (WET SEASON, JANUARY 1992)**

916055.24/P2SK039

FIGURE SW-17

and increase slightly in Reach C. No concentrations exceeded the maximum runoff surface water concentration for calcium. Dry season calcium concentrations were higher than the transitional and wet season surface water samples.

5.1.8.4 Onsite Sediment. Calcium was detected in all onsite sediment samples collected during the transitional season. Concentrations ranged from 3,030 mg/kg at Location 2516 to 18,300 mg/kg at Location 2509.

Calcium was detected in all onsite sediment samples collected during the dry season. Concentrations ranged from 2,290 mg/kg at Location 2513 to 18,200 mg/kg at Location 2509. Dry weight calcium concentrations increased then declined in Reach A before increasing gradually through Reach B. Dry weight concentrations peaked in Reach C at Location 2509, then declined for the remaining sections of the surface water channel. When normalized to percent fine-grain material, the most elevated concentrations were detected in samples collected in Reach A and C. Normalized concentrations increased steadily from the northern section of Reach B, declined at Location 2521, and then rose and fell twice more before peaking in Reach C.

Calcium was detected in all onsite sediment samples collected during the wet season at concentrations ranging from 1,170 mg/kg (below CRDL) at Location 2516 to 16,700 mg/kg at Location 2510. Dry weight concentrations of calcium did not vary significantly except in Reach C where two locations (2510 and 2509) exhibited the most elevated concentrations. When normalized to percent fine-grain material, the most elevated concentrations were detected in samples collected in Reach A and in the northern section of Reach B. In addition, normalized concentrations were elevated in Reach C at Locations 2510 and 2509. Maximum calcium concentrations were similar for all seasonal sediment samples.

5.1.8.5 Runoff. Calcium was detected in surface water samples collected at runoff Location 2515. The biweekly surface water runoff concentrations ranged from 3,830 $\mu\text{g/L}$ (below CRDL) to 6,790 $\mu\text{g/L}$. The stormwater runoff

concentration was 7,200 $\mu\text{g/L}$, which is greater than all the biweekly surface water runoff concentrations, but within the range of runoff concentrations.

5.1.9 Chromium (Total)

Chromium is a naturally occurring transitional metal. Hem (1989) reported that concentrations of chromium are commonly less than 10 $\mu\text{g/L}$ in natural waters that have not been affected by waste disposal. In the vicinity of STF, a concentration of 111 $\mu\text{g/L}$ was detected in a sample collected from a heavy flow of a leachate/runoff seep from a catch basin in the Leach Creek area in January 1983 (Lum and Turney 1985).

Chromium III eventually is expected to precipitate in sediment, whereas, chromium IV is predominantly present in soluble form. In suspended material and sediment of water bodies, the level of chromium ranges from 1 mg/L to 500 mg/kg (ATSDR 1987g). Concentrations of chromium, ranging from 22 mg/kg to 47 mg/kg, were detected in sediment sampled in the Leach Creek area (Lum and Turney 1985).

5.1.9.1 Background. Total chromium was detected below the CRDL at 9.89 $\mu\text{g/L}$ in a sample collected at background Location 2541 during the dry season event, which was below AFWQC (see Table SW-6). Total chromium was not detected in samples collected during the wet season sampling event.

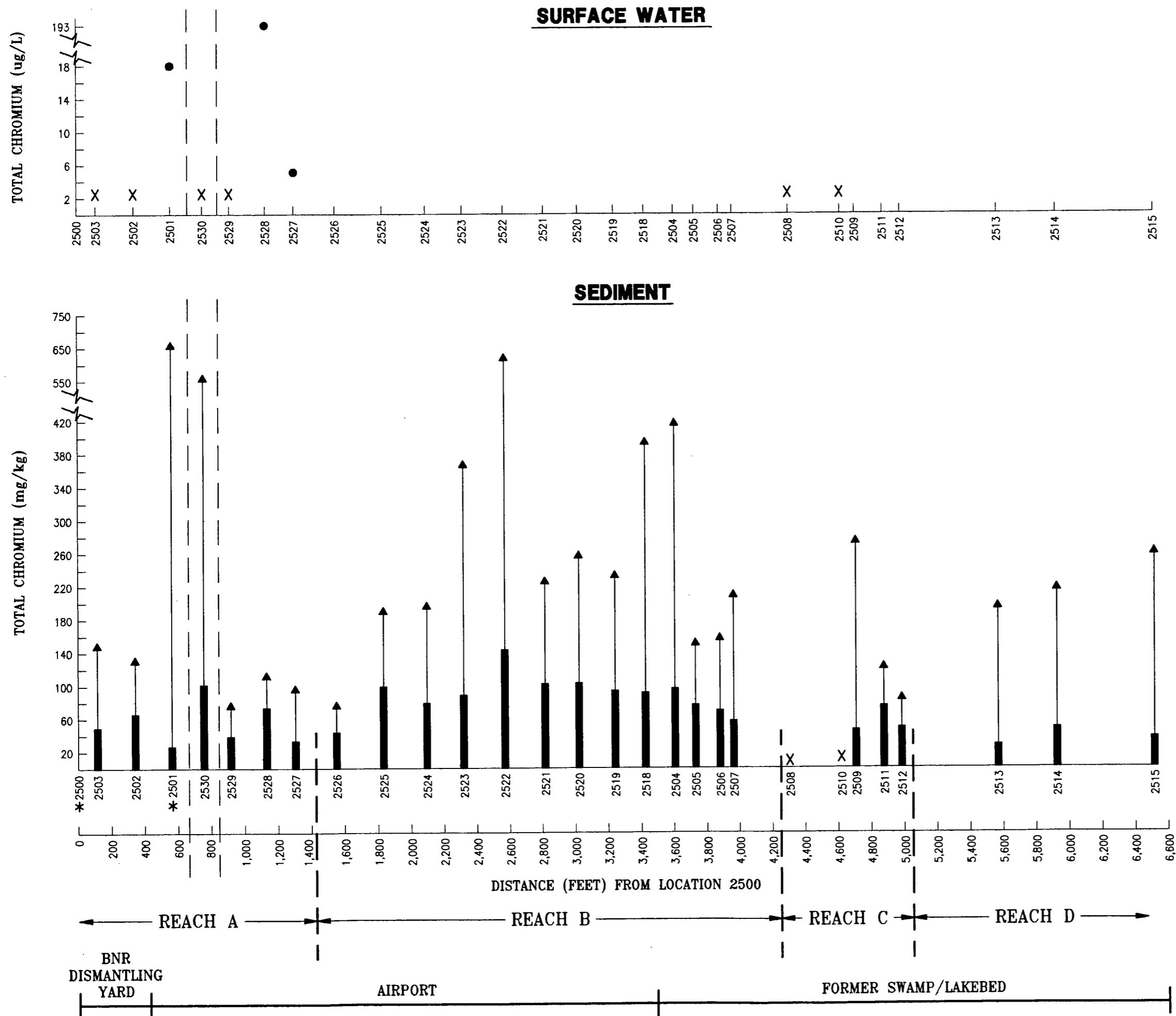
5.1.9.2 Runon. Concentrations of total chromium were detected in approximately half the surface water runoff samples collected at both locations. Total chromium was detected in only one monthly runoff sample collected at Location 2500 (7.2 $\mu\text{g/L}$, below CRDL). Total chromium concentrations ranged from undetected to 34.9 $\mu\text{g/L}$ (two below CRDL) in the monthly runoff samples collected at Location 2501 (see Table SW-7). Total chromium concentrations ranged from undetected to 12.6 $\mu\text{g/L}$ in stormwater runoff samples collected at Location 2500 and from

undetected to 50.4 $\mu\text{g/L}$ in the stormwater runoff samples collected at Location 2501. AFWQC for total chromium were not exceeded.

Generally, total chromium concentrations in stormwater runoff were higher than concentrations in monthly runoff at both locations (see Appendix SW-B). The runoff monthly and stormwater concentrations detected in samples collected at Location 2501 were greater than those detected at Location 2500. Total chromium concentrations detected in samples collected at Location 2501 were similar except the high concentrations of total chromium detected in the samples collected during the 100-year storm on 4 April 1991.

Concentrations of total chromium detected in surface water monthly runoff samples exceeded the range of background surface water concentrations in three samples at Location 2501. Concentrations of total chromium detected in the stormwater runoff samples exceeded the range of background surface water concentrations in one sample collected at Location 2500 and in seven samples collected at Location 2501. Total chromium concentrations detected in samples collected from Location 2500 were similar to the concentrations detected in natural waters (10 $\mu\text{g/L}$). Concentrations detected in samples collected at Location 2501 exceeded the concentrations detected in natural waters, but were less than the concentrations detected in the vicinity of STF (Lum and Turney 1985).

5.1.9.3 Onsite Surface Water. Total chromium was detected only in onsite surface water samples collected during the dry and wet seasons (i.e., was not detected in surface water samples collected during the transitional season). Concentrations of total chromium in onsite surface water and sediment samples collected during the dry season are presented in Appendix SW-D and Figure SW-18. Total chromium was detected in only three surface water samples. Concentrations ranged from undetected to 193 $\mu\text{g/L}$ at Location 2528 (see Table SW-8). The concentration associated with the sample collected from Location 2528 exceeded the maximum runoff surface water concentration of 50.4 $\mu\text{g/L}$. The AFWQC for



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SOUTH TACOMA FIELD
TACOMA, WA

**TOTAL CHROMIUM CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (DRY SEASON, AUGUST 1991)**

916055.24/P2SK016

FIGURE SW-18

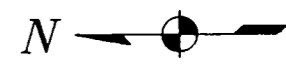
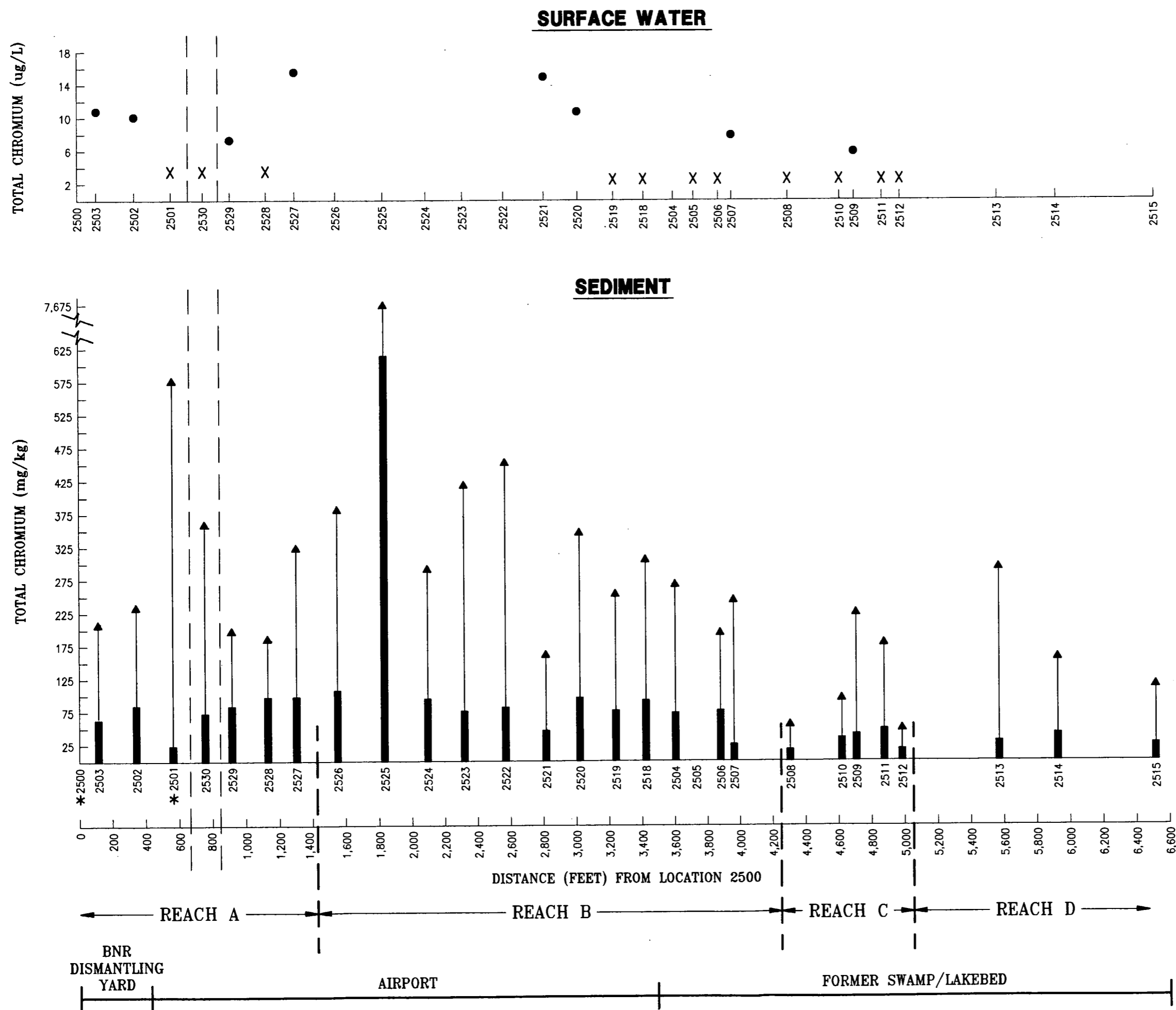
total chromium (1,341 $\mu\text{g/L}$) was not exceeded at any location for dry season surface water samples.

Concentrations of total chromium in surface water and sediment samples collected during the wet season are presented in Appendix SW-D and Figure SW-19. Total chromium was detected in only eight surface water samples. Concentrations of total chromium ranged from undetected to 15.5 $\mu\text{g/L}$ at Location 2527 with the most elevated concentrations in Reach B. No concentrations exceeded the maximum runoff surface water concentration. The AFWQC for total chromium (768 $\mu\text{g/L}$) was not exceeded at any location.

The maximum surface water total chromium concentration in the dry season was more than 1 order of magnitude greater than concentrations in the wet and transitional seasons. Generally, the detected onsite surface water concentrations were greater than those reported for natural waters (10 $\mu\text{g/L}$; Hem 1989). The maximum total chromium concentration for surface water also exceeded concentrations detected in Leach Creek area (Lum and Turney 1985).

5.1.9.4 Onsite Sediment. Total chromium was detected in all onsite sediment samples collected during the transitional season. Concentrations ranged from 24.2 mg/kg at Location 2516 to 73.2 mg/kg at Location 2506.

Total chromium was detected in all but two onsite sediment samples collected during the dry season. Concentrations ranged from undetected to 143 mg/kg at Location 2522. Based on dry weight concentrations, no trends were discernible except possibly in Reach B, where dry weight concentrations increased from Location 2526 to Location 2522 and then decreased for the remainder of the surface water channel. When normalized to percent fine-grain material, concentrations of total chromium showed no apparent trends, except possibly in Reach D. In this reach, normalized concentrations increased from the northern locations to the southern locations.



LEGEND

- SURFACE WATER CONCENTRATION
- DRY-WEIGHT NORMALIZATION
- ▲ FINE-GRAIN NORMALIZATION
- X 1/2 DETECTION LIMIT
- * SURFACE WATER RUNON LOCATION

Kennedy/Jenks Consultants

SOUTH TACOMA FIELD
TACOMA, WA

**TOTAL CHROMIUM CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (WET SEASON, JANUARY 1992)**

916055.24/P2SK040

FIGURE SW-19

Total chromium was detected in all onsite sediment samples collected during the wet season. Concentrations ranged from 15.5 mg/kg at Location 2516 to 614 mg/kg at Location 2525. When normalized to percent fine-grain material, the most elevated concentrations were detected in samples collected from Reach A and the northern section of Reach B. Concentrations then generally declined from the northern to the southern locations. Maximum total chromium concentrations were approximately four to eight times greater in the wet season sediment samples compared to the transitional and dry season sediment samples.

5.1.9.5 Runoff. Total chromium was detected at 8.0 $\mu\text{g/L}$ (below CRDL) in only one biweekly surface water runoff sample collected from Location 2515 (see Table SW-9). The detected concentration was below the AFWQC. The detected concentration was greater than the range of runoff concentrations detected at Location 2500, but less than 10 $\mu\text{g/L}$ (common in natural waters).

5.1.10 Cobalt

Cobalt concentrations should generally be detected at no more than a few micrograms per liter in uncontaminated waters. Co-precipitation or adsorption of cobalt by oxides of manganese and iron control the amount that can occur in solution in natural waters (Hem 1989).

Cobalt was detected in only runoff and onsite surface water and sediment samples [i.e., cobalt was not detected in background, onsite (transitional season), and runoff surface water samples]. WQC have not been proposed by EPA.

5.1.10.1 Runoff. Cobalt was detected (997 $\mu\text{g/L}$) in only one monthly runoff sample collected at Location 2500 (see Table SW-7). Cobalt was detected in 3 out of 10 monthly runoff samples collected at Location 2501 (all of which were below CRDL). Cobalt was undetected in the stormwater runoff samples collected at Location 2500. Cobalt was detected in 9 of 11 stormwater runoff samples

collected at Location 2501. These stormwater runoff concentrations ranged from undetected to 15 $\mu\text{g/L}$ (all below CRDL).

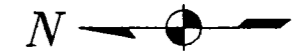
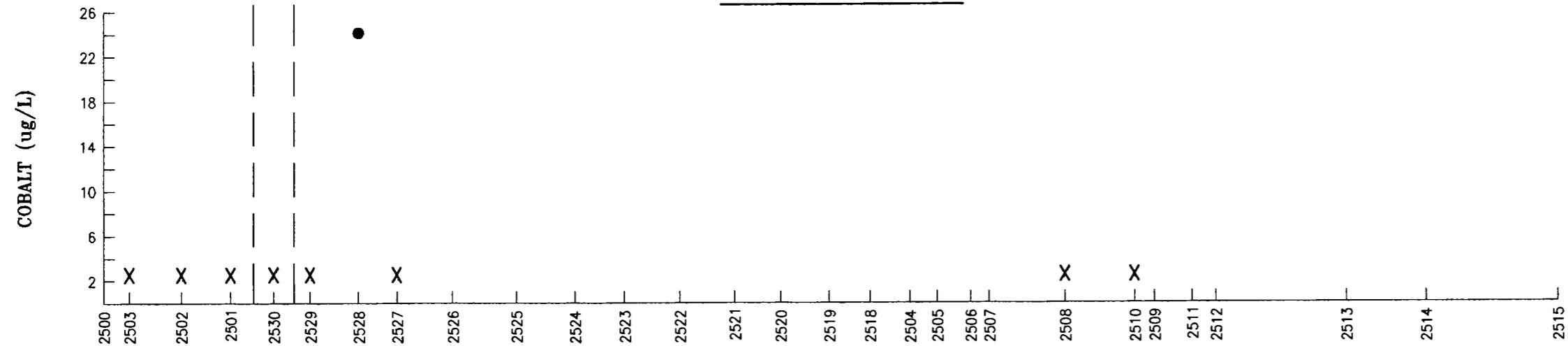
Stormwater runoff concentrations detected in runoff monthly and stormwater were consistently uniform except for the one monthly surface water runoff concentration (997 $\mu\text{g/L}$) detected at Location 2500 (see Appendix SW-B). Concentrations detected at Location 2501 and the one at Location 2500 were greater than the concentration range for the background surface water. However, all concentrations were less than reported concentrations of uncontaminated waters (Hem 1985).

5.1.10.2 Onsite Surface Water. Concentrations of cobalt in onsite surface water and sediment samples collected during the dry season are presented in Appendix SW-D and Figure SW-20. Cobalt was detected in only one onsite surface water sample (Location 2528) at a concentration of 24.1 $\mu\text{g/L}$ (see Table SW-8). This concentration is below the CRDL and below the maximum runoff surface water concentration of 997 $\mu\text{g/L}$.

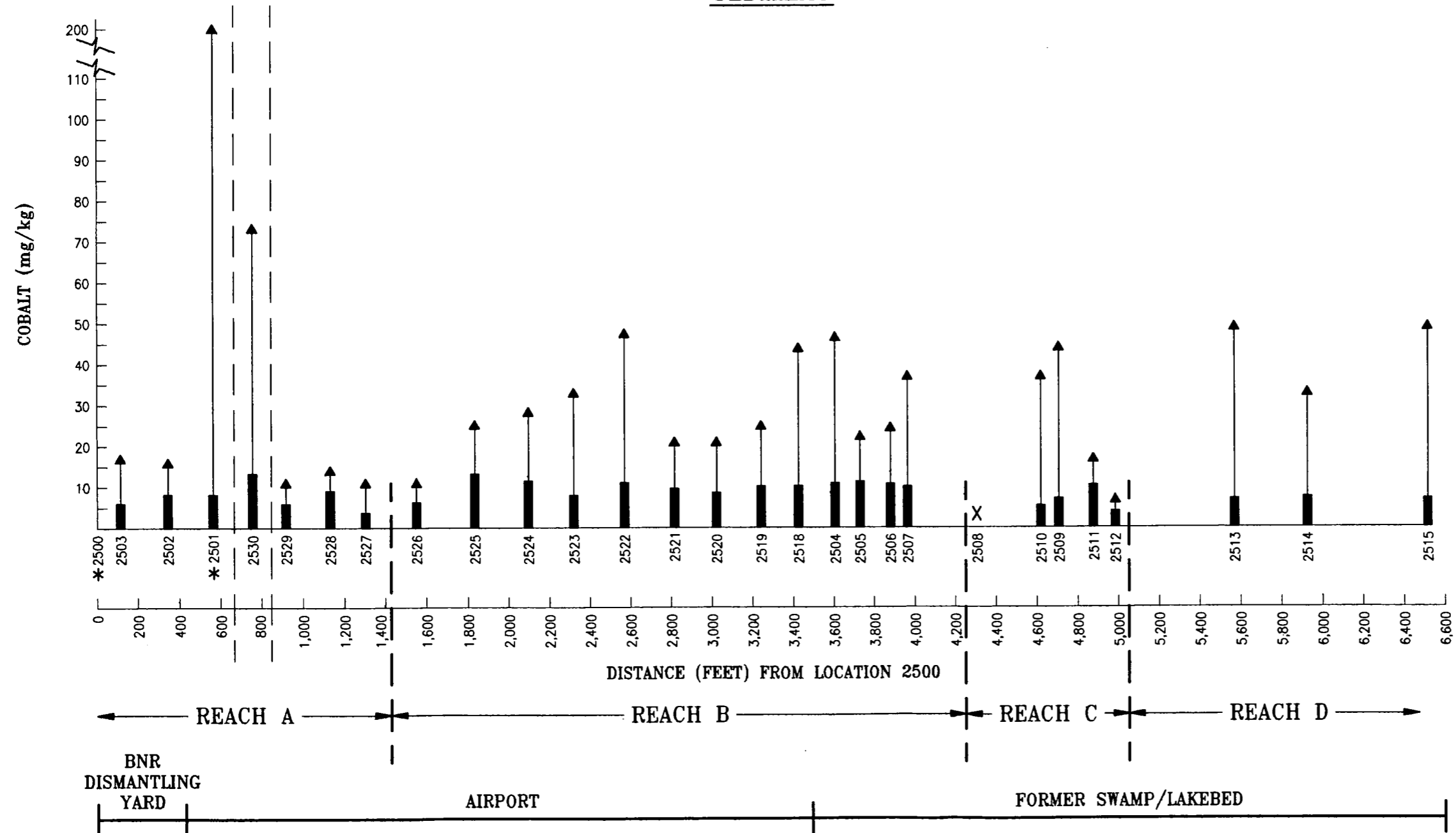
Concentrations of cobalt in onsite surface water and sediment samples collected during the wet season are presented in Appendix SW-D and Figure SW-21. Five onsite surface water samples exhibited detectable concentrations of cobalt. Concentrations, which were all below the CRDL, ranged from undetected to 7.7 $\mu\text{g/L}$ at Location 2507. The most elevated concentrations were detected in samples collected from the southern section of Reach B. All concentrations were below the maximum runoff surface water concentration for cobalt.

The maximum cobalt concentration was approximately three times higher in onsite (dry season) surface water sample compared to wet season surface water cobalt concentrations. All detected cobalt concentrations were less than reported concentrations of uncontaminated waters.

SURFACE WATER



SEDIMENT



LEGEND

- SURFACE WATER CONCENTRATION
- DRY-WEIGHT NORMALIZATION
- ▲ FINE-GRAIN NORMALIZATION
- X 1/2 DETECTION LIMIT
- * SURFACE WATER RUNON LOCATION

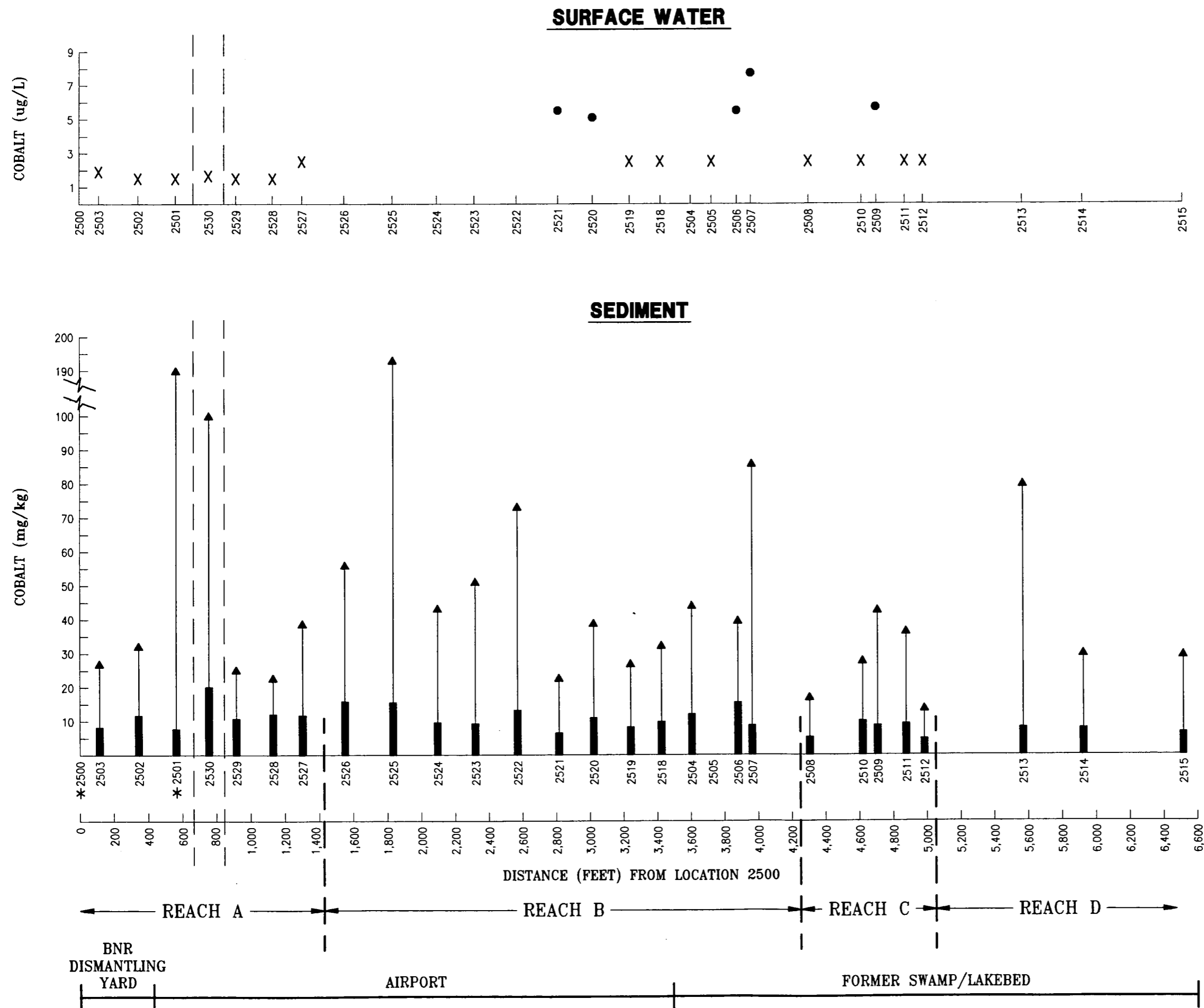
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SOUTH TACOMA FIELD
TACOMA, WA

**COBALT CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (DRY SEASON, AUGUST 1991)**

916055.24/P2SK017

FIGURE SW-20



LEGEND

- SURFACE WATER CONCENTRATION
- DRY-WEIGHT NORMALIZATION
- ▲ FINE-GRAIN NORMALIZATION
- X 1/2 DETECTION LIMIT
- * SURFACE WATER RUNON LOCATION

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SOUTH TACOMA FIELD
TACOMA, WA

**COBALT CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (WET SEASON, JANUARY 1992)**

916055.24/P2SK041

FIGURE SW-21

5.1.10.3 Onsite Sediment. Cobalt was detected in all sediment samples collected during the transitional season. Concentrations ranged from 6.5 mg/kg at Location 2516 to 10.8 mg/kg at Location 2509 (three of which were below CRDL).

Cobalt was detected in all but one sediment sample collected during the dry season. Concentrations ranged from undetected to 13.2 mg/kg at Location 2530 (all were below CRDL). Generally, dry weight cobalt concentrations were relatively constant along the length of the surface water channel and typically below 10 mg/kg. When normalized to percent fine-grain material, Reach A exhibited the highest normalized concentrations because of the low quantity of fine material in this section. In the other reaches, no discernible trend was apparent.

Cobalt was detected in all sediment samples collected during the wet season. Concentrations, which were all below the CRDL, ranged from 2.5 mg/kg at Location 2516 to 20.0 mg/kg at Location 2530. Dry weight cobalt concentrations did not appear to show any discernible trends. When normalized to percent fine-grain material, concentrations generally trended downward from the northern to the southern end of the channel, although relatively high normalized concentrations were detected in samples collected from Locations 2507 and 2513. The high normalized concentration at Location 2507 is due to a relatively high dry weight concentration coupled with a relatively low (39 percent) amount of fine-grain material. The high normalized concentration at Location 2513 is the result of a very low (10 percent) quantity of fine-grain material. Maximum cobalt concentrations were approximately equivalent for all seasonal sediment samples.

5.1.11 Copper

The median concentration of copper in natural water is 4-10 $\mu\text{g/L}$. Sixty-eight percent of releases to water is estimated to be from natural weathering or from disturbed soil. In the National Urban Runoff Program, copper was the one of the most frequently detected and was detected at concentrations of 1 to 100 $\mu\text{g/L}$ in

runoff samples collected. Copper levels in surface waters range from 0.5 to 1,000 $\mu\text{g/L}$ with a median of 10 $\mu\text{g/L}$ (ATSDR 1989b; Hem 1989). In the vicinity of STF, copper concentrations detected in January 1983 in the Leach Creek area were below 20 $\mu\text{g/L}$ (Lum and Turney 1985).

Sediment is an important sink and reservoir for copper, with relatively clean sediment copper concentrations less than 50 mg/kg. Copper, generally found in the form of particulate matter (copper or copper compounds), co-precipitates by oxides and adsorption on mineral surfaces and to organic matter (ATSDR 1989b; Hem 1989). In sediment, copper is generally associated with fine-grain sediment (i.e., silt and clay) and concentrations of copper were correlated negatively with the percentage of sand in the sediment. In the vicinity of STF, copper was detected in the sediment around the Leach Creek area at 38 to 140 mg/kg (Lum and Turney 1985).

5.1.11.1 Background. Copper was detected in all background samples except at Location 2500 during the dry season event. Dry season background concentrations ranged from undetected to 11.8 $\mu\text{g/L}$ (two reported concentrations were below CRDL; see Table SW-6). The copper concentration detected in the dry season event sample collected at Location 2543 exceeded the 1-hour average WQC (3.64 $\mu\text{g/L}$).

Copper concentrations were detected in samples collected during the wet season event at all background locations except Locations 2500 and 2540. The background wet season event copper concentrations (all below CRDL) ranged from undetected to 11.2 $\mu\text{g/L}$. AFWQC for copper was not exceeded by the wet season event copper concentrations. Generally, the copper concentrations detected in the dry season background samples were slightly higher than those detected in the wet season samples.

5.1.11.2 Runon. Copper was detected at both surface water runon locations. The monthly runon concentrations of copper ranged from undetected to 38.5 $\mu\text{g/L}$ at

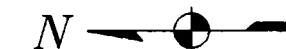
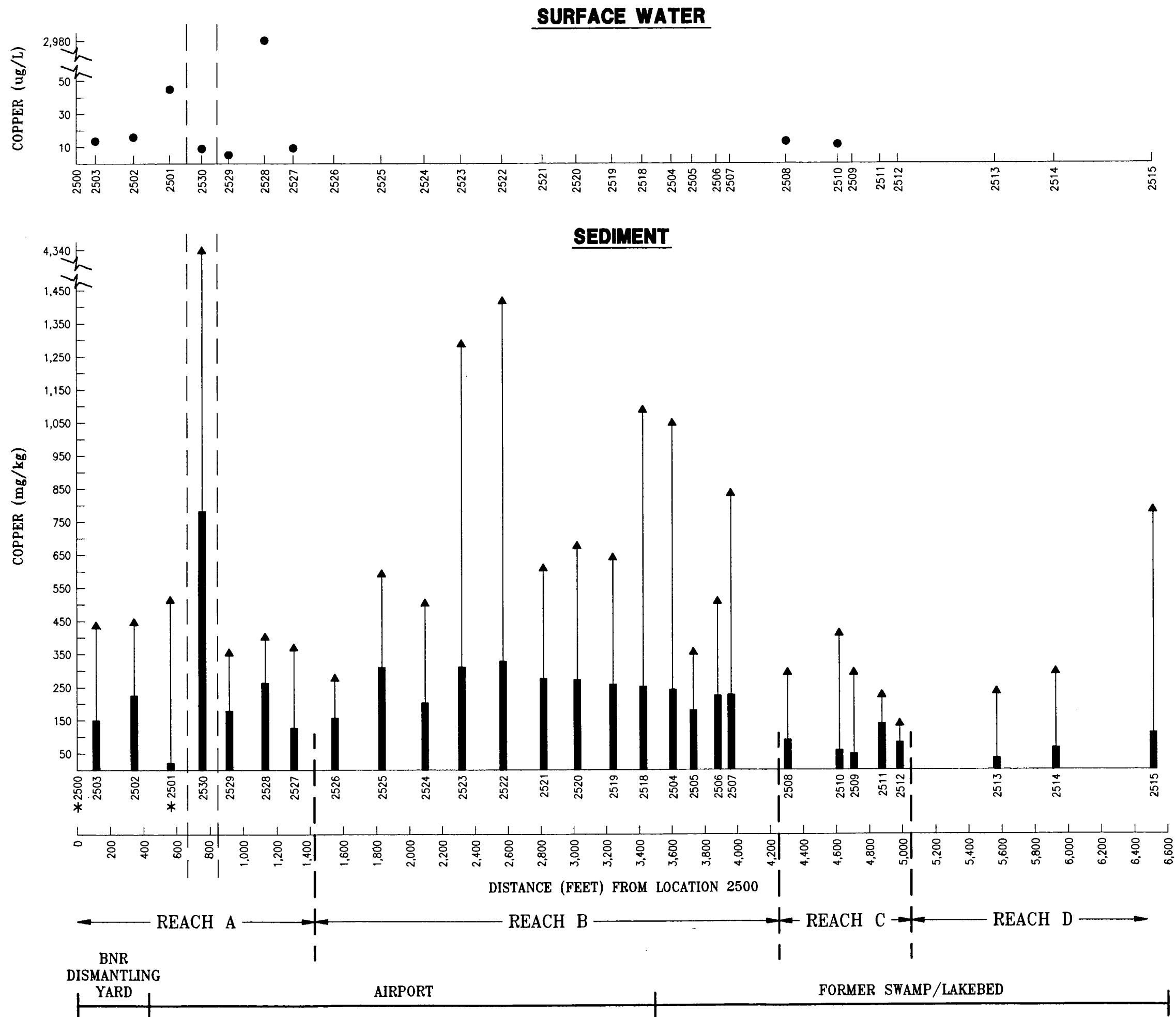
Location 2500 and ranged from undetected to 46.1 $\mu\text{g/L}$ at Location 2501 (see Table SW-7). The stormwater runoff concentrations of copper ranged from 7.0 $\mu\text{g/L}$ to 52.2 $\mu\text{g/L}$ at Location 2500 and from 14 $\mu\text{g/L}$ to 48.6 $\mu\text{g/L}$ at Location 2501.

Monthly runoff sample concentrations detected at Locations 2500 (four exceedances) and 2501 (two exceedances) exceeded the 1-hour average WQC. All stormwater runoff concentrations detected at both locations exceeded the 1-hour average WQC.

Generally, copper concentrations in stormwater runoff samples were higher than concentrations in monthly runoff samples at both locations (see Appendix SW-B). The runoff stormwater concentrations detected in samples collected at Location 2501 were greater than the concentrations detected at Location 2500. Seasonal variations were apparent with copper concentrations increasing during the months of June to October at both locations. Copper concentrations in samples collected at both locations were detected at higher values during the 100 year storm on 4 April 1991.

The concentrations for the monthly runoff samples exceeded the background range, three samples collected at Location 2500, and two samples collected at Location 2501. The concentrations for the stormwater runoff samples exceeded the background range at both locations. In general, copper concentrations for the runoff samples collected at both locations were above the reported regional median (10 $\mu\text{g/L}$) and local copper concentrations (Lum and Turney 1985; ATSDR 1989b; Hem 1989).

5.1.11.3 Onsite Surface Water. Copper was not detected in onsite surface water samples collected during the transitional season. Concentrations of copper in onsite surface water and sediment samples collected during the dry season are presented in Appendix SW-D and Figure SW-22. Concentrations in onsite surface water samples ranged from 5.2 $\mu\text{g/L}$ at Location 2529 to 2,980 $\mu\text{g/L}$ at Location 2528



LEGEND

- SURFACE WATER CONCENTRATION
- DRY-WEIGHT NORMALIZATION
- ▲ FINE-GRAIN NORMALIZATION
- X 1/2 DETECTION LIMIT
- * SURFACE WATER RUNON LOCATION

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SOUTH TACOMA FIELD
TACOMA, WA

**COPPER CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (DRY SEASON, AUGUST 1991)**

916055.24/P2SK018

FIGURE SW-22

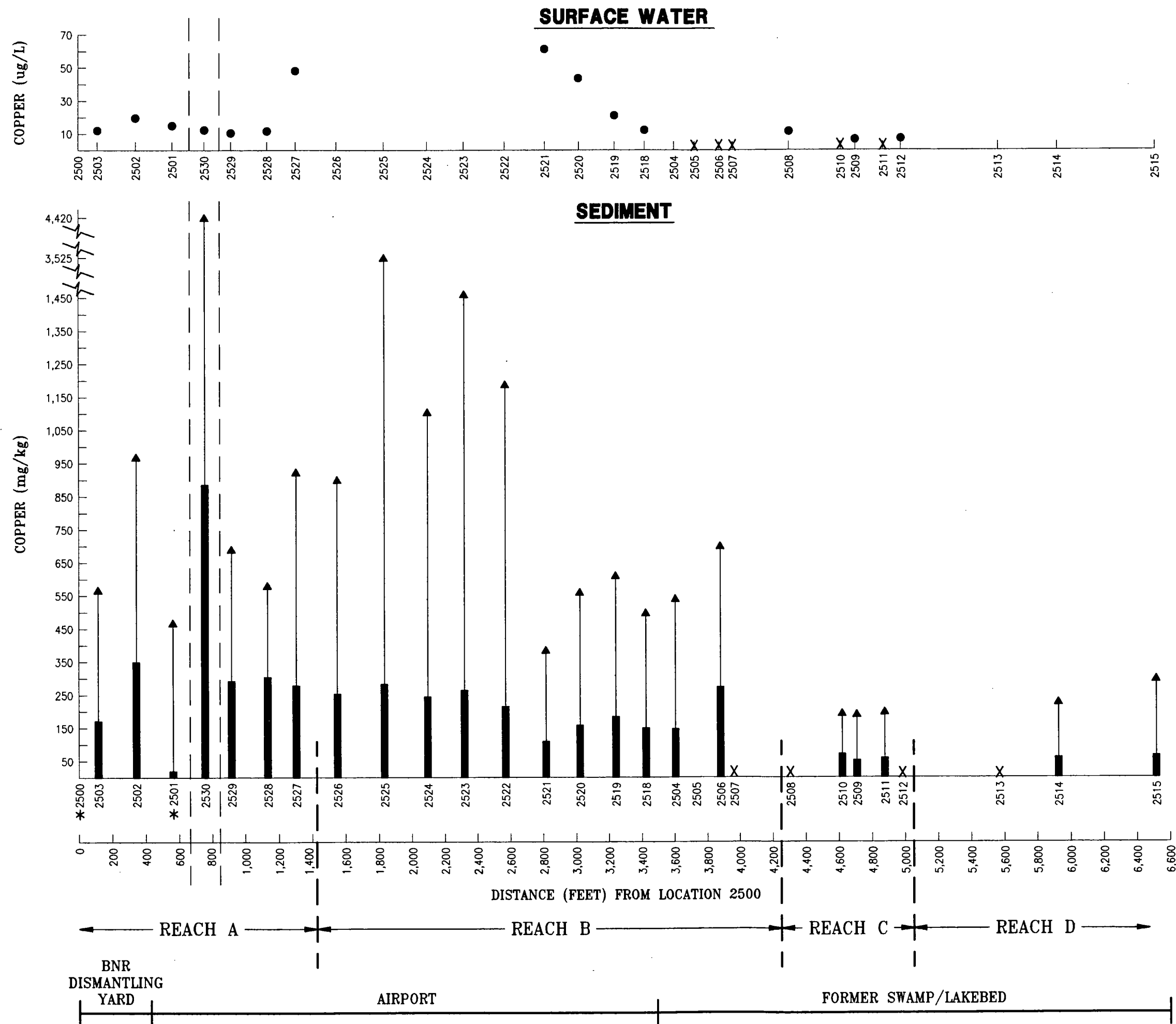
(see Table SW-8). Five detected concentrations were below the CRDL. Most detected concentrations were associated with samples collected from Reach A. The concentration associated with the sample collected from Location 2528 exceeded the maximum runoff surface water concentration of 52.2 $\mu\text{g/L}$. The AFWQC for copper (13 $\mu\text{g/L}$) was exceeded at five sampling locations.

Concentrations of copper in onsite surface water and sediment samples collected during the wet season are presented in Appendix SW-D and Figure SW-23. Copper was detected in 16 onsite surface water samples collected during the wet season. Concentrations ranged undetected to 61.1 $\mu\text{g/L}$ at Location 2521. The most elevated concentrations were detected in samples collected from the southern section of Reach B. No concentrations exceeded the maximum runoff surface water concentration for copper. The AFWQC for copper (6.8 $\mu\text{g/L}$) was exceeded at 13 sample locations, primarily in Reaches A and B.

The maximum surface water copper concentration in the dry season was more than two orders of magnitude greater than in the wet season. Generally, onsite surface water copper concentrations were greater than concentrations reported in natural waters (4-10 $\mu\text{g/L}$) but within national and regional copper concentration ranges.

5.1.11.4 Onsite Sediment. Copper was detected in all sediment samples collected during the transitional season (see Appendix SW-D). Concentrations ranged from 9.2 mg/kg at Location 2516 to 230 mg/kg at Location 2506.

Copper was detected in all onsite sediment samples collected during the dry season. Concentrations ranged from 12.8 mg/kg at Location 2516 to 781 mg/kg at Location 2530. Dry weight copper concentrations were generally higher in Reach B than the other reaches, except for the sample collected in Reach A at Location 2530. The copper concentration in this sample was significantly more elevated compared to other sample concentrations.



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SOUTH TACOMA FIELD
TACOMA, WA

COPPER CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (WET SEASON, JANUARY 1992)

916055.24/P2SK042

FIGURE SW-23

When normalized to percent fine-grain material, copper concentrations exhibited a pattern similar to that for total chromium. Generally, the samples having lower amounts of fine-grain material exhibited high normalized concentrations. No patterns were discernible, except for in Reach D where normalized concentrations increased gradually from the northern to southern locations south of Location 2500.

Copper was detected in all but five onsite sediment samples collected during the wet season. Concentrations ranged undetected to 884 mg/kg at Location 2530. Dry weight concentrations were the most elevated in Reach A and the northern section of Reach B. Concentrations then generally declined with distance from the northern section of Reach B through Reach D. When normalized to percent fine-grain material, elevated concentrations were noted in Reach A and the northern section of Reach B. Normalized concentrations decreased dramatically in the southern section of Reach B and in Reaches C and D.

Maximum sediment copper concentrations were approximately equivalent during the dry and wet seasons. These concentrations were approximately three to four times greater than the transitional season concentration.

5.1.11.5 Runoff. Copper was detected in biweekly surface water and stormwater runoff samples collected from Location 2515. The biweekly surface water runoff concentrations ranged from undetected to 9.2 $\mu\text{g/L}$. The stormwater runoff concentration was 5.6 $\mu\text{g/L}$ (below CRDL). All of the detected concentrations exceeded the AFWQC. Runoff concentrations were within the range of runoff concentrations and the range for natural waters (4-10 $\mu\text{g/L}$).

5.1.12 Cyanide

Cyanide has been detected at concentrations ranging from 2 to 33 $\mu\text{g/L}$ in surface waters and urban runoff throughout the U.S. (detected in 16 percent of urban

runoff samples collected). Anthropogenic sources are responsible for nearly all the cyanide found in the environment (ATSDR 1988a).

Cyanide was detected in only onsite surface water (wet season) and sediment samples [i.e., cyanide was not detected in background, onsite (transitional and dry season) and runoff surface water]. Storm and monthly surface water runoff samples were not analyzed for cyanide.

Cyanide was detected in one onsite surface water sample collected from Location 2509 during the wet season (see Table SW-8). The reported concentration (10.4 $\mu\text{g/L}$) was within the range of concentrations detected in U.S. surface waters and urban runoff.

Cyanide was detected in three onsite sediment samples collected during the transitional season. Concentrations ranged from undetected to 0.9 mg/kg at Location 2511. Cyanide was not detected in sediment samples collected during the dry season, and in only one sediment sample collected during the wet season (1.3 mg/kg at Location 2511).

5.1.13 Iron

Although iron is the second most abundant metallic element in the Earth's outer crust, concentrations present in surface water generally are small. Iron is present in organic debris and in plant debris in soils. Higher iron concentrations in a simple hydraulic system could result from interactions between oxidized iron minerals and organic matter (Hem 1989). The USGS attributed elevated iron concentration in the Puget Sound region to naturally occurring iron in groundwater. In the vicinity of STF, concentrations of iron in surface waters were detected above 4,000 $\mu\text{g/L}$ in the Leach Creek area in January 1983 (Lum and Turney 1985).

5.1.13.1 Background. Iron was detected in all of the background samples collected during both seasons, except for samples collected at Location 2540 during the dry season event. Background concentrations of iron collected during the dry season event ranged from undetected to 1,220 $\mu\text{g/L}$ (see Table SW-6). Background concentrations of iron collected during the wet season event ranged from 76.1 $\mu\text{g/L}$ (below CRDL) to 1,990 $\mu\text{g/L}$. No WQC have been proposed by EPA for iron. No trend in a seasonal variation of detected iron concentrations was discernible.

5.1.13.2 Runon. Iron was detected in surface water runon samples collected at both locations. Monthly runon surface water concentrations ranged from undetected to 3,830 $\mu\text{g/L}$ at Location 2500 and ranged from undetected to 22,500 $\mu\text{g/L}$ at Location 2501 (see Table SW-7). Stormwater runon concentrations ranged from 634 $\mu\text{g/L}$ to 4,160 $\mu\text{g/L}$ at Location 2500 and ranged from 2,510 to 26,500 $\mu\text{g/L}$ at Location 2501.

Generally, iron concentrations in stormwater runon were higher than concentrations in monthly runon at both locations (see Appendix SW-B). The runon monthly and stormwater concentrations were higher at Location 2501 than at Location 2500. Seasonal variations were apparent with iron concentrations increasing during the months of June to January at Location 2501 and during the months of July and October at Location 2500. The one exception is the high concentrations of iron detected in the samples collected during the 100-year storm on 4 April 1991.

High concentrations of iron are reported for the Puget Sound region. Iron concentrations detected at Location 2500 were lower than those detected in the USGS study conducted in the vicinity of STF. However, the stormwater runon concentrations were detected at higher concentrations at Location 2501 than the USGS study iron concentrations (Lum and Turney 1985).

5.1.13.3 Onsite Surface Water. Concentrations of iron in onsite surface water and sediment samples collected during the transitional season are presented in Appendix

SW-D. Iron was detected at estimated concentrations in all surface water samples collected during the transitional season. Concentrations ranged from 292 $\mu\text{g/L}$ at Location 2511 to 1,960 $\mu\text{g/L}$ at Location 2509 (see Table SW-8). No concentrations exceeded the maximum runon surface water concentration of 26,500 $\mu\text{g/L}$.

Concentrations of iron in onsite surface water and sediment samples collected during the dry season are presented in Appendix SW-D and Figure SW-24. Concentrations in surface water samples ranged from 427 $\mu\text{g/L}$ at Location 2510 to 58,700 $\mu\text{g/L}$ at Location 2528. Most detected concentration were associated with samples collected from Reach A. The maximum runon surface water concentration was exceeded at Location 2528.

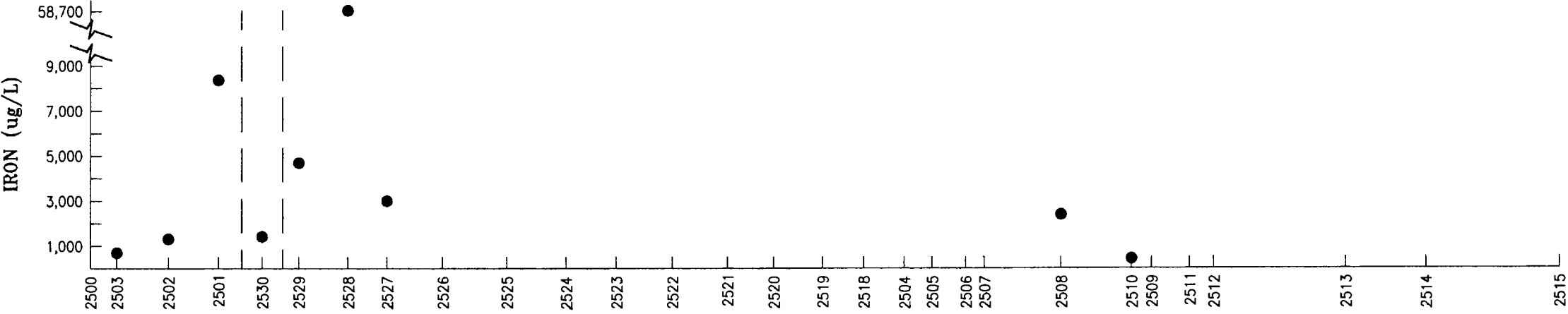
Concentrations of iron in onsite surface water and sediment samples collected during the wet season are presented in Figure SW-25. Concentrations in surface water samples ranged from 516 $\mu\text{g/L}$ at Location 2516 to 4,910 $\mu\text{g/L}$ at Location 2527. When graphically presented, surface water concentrations appeared to increase in the northern section of Reach B from low levels in Reach A and then declined in the southern section of Reach B and in Reach C. No concentrations exceeded the maximum runon surface water concentration for iron.

Maximum onsite surface water iron concentrations were more than 1 order of magnitude greater in dry season samples compared to transitional and wet season samples. Iron concentrations detected in onsite surface samples were lower than those detected in the USGS study conducted in the vicinity of STF.

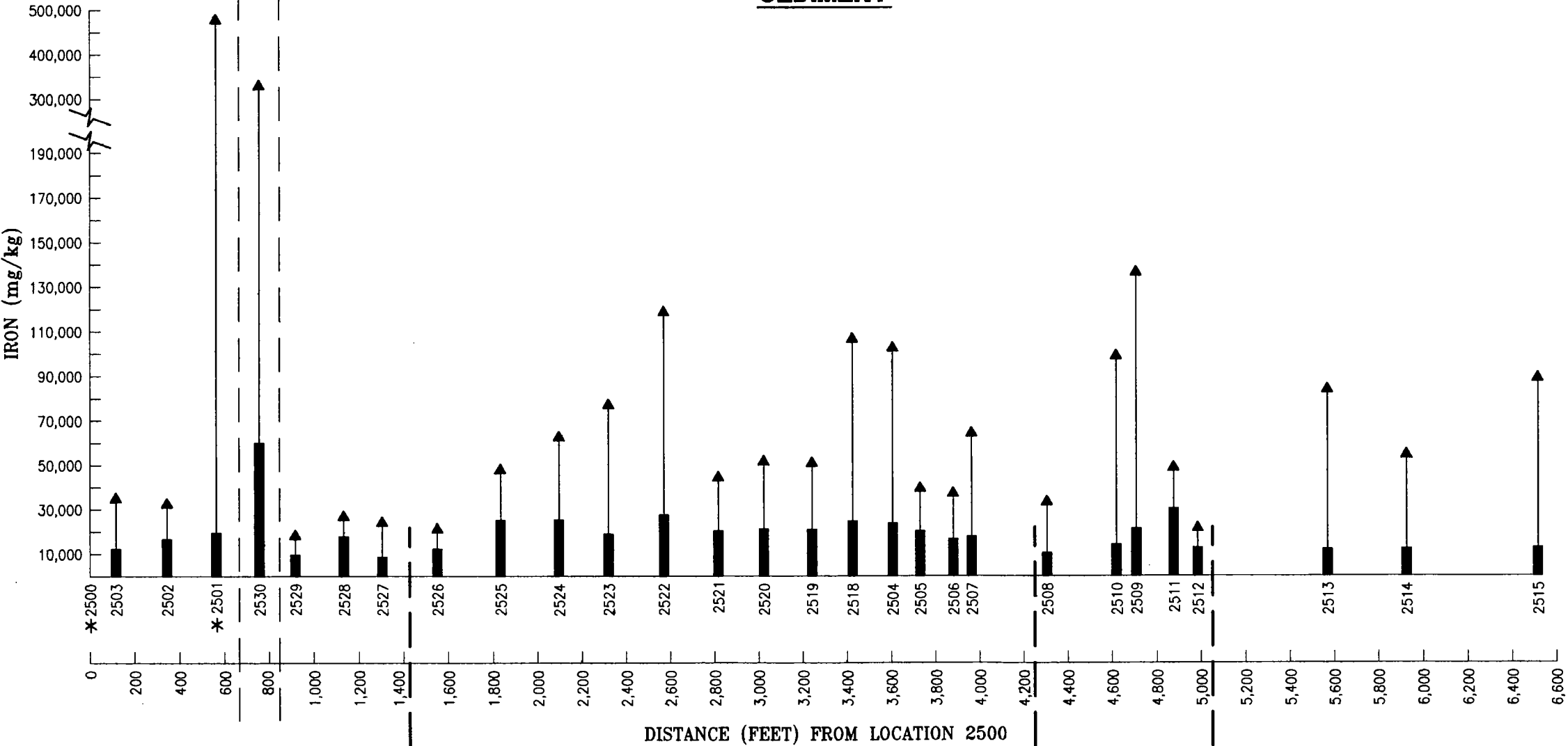
5.1.13.4 Onsite Sediment. Iron was detected in all onsite sediment samples collected during the transitional season. Concentrations ranged from 1,590 mg/kg at Location 2516 to 25,000 mg/kg at Location 2511.

Iron was detected in all onsite sediment samples collected during the dry season. Concentrations ranged from 8,350 mg/kg at Location 2527 to 59,800 mg/kg at

SURFACE WATER



SEDIMENT



LEGEND

- SURFACE WATER CONCENTRATION
- DRY-WEIGHT NORMALIZATION
- ▲ FINE-GRAIN NORMALIZATION
- X 1/2 DETECTION LIMIT
- * SURFACE WATER RUNON LOCATION

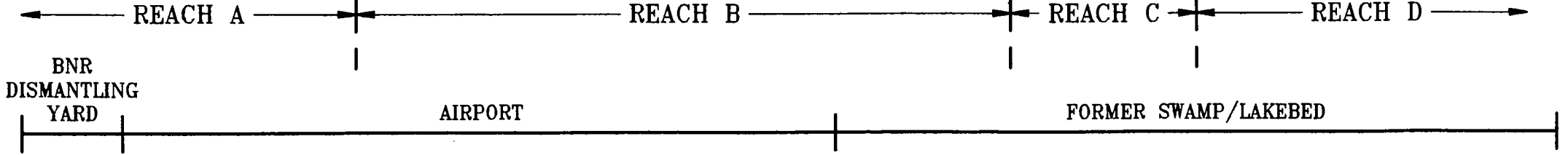
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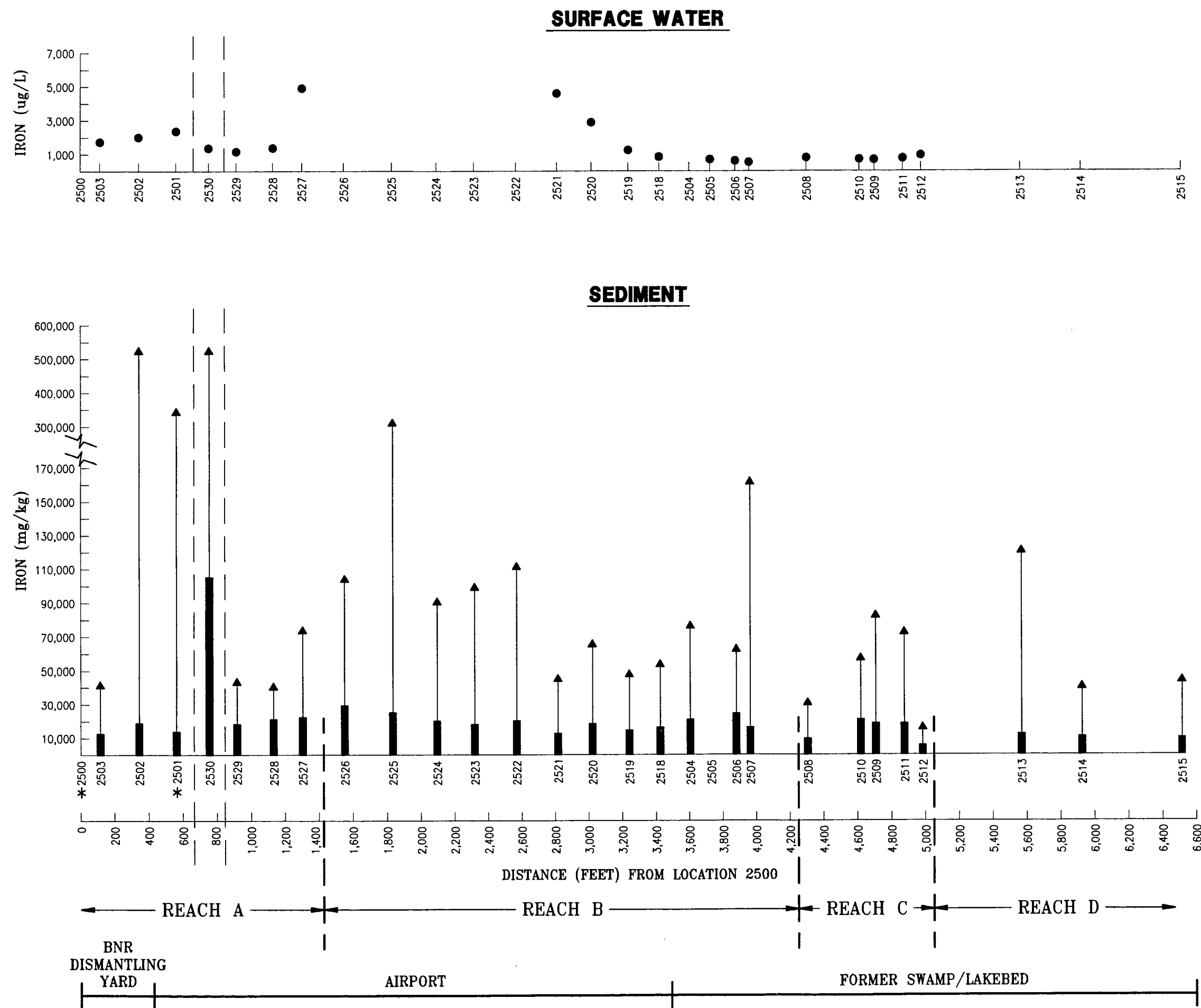
SOUTH TACOMA FIELD
TACOMA, WA

**IRON CONCENTRATIONS FOR
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SAMPLES (DRY SEASON, AUGUST 1991)**

916055.24/P2SK019

FIGURE SW-24





LEGEND

- SURFACE WATER CONCENTRATION
- DRY-WEIGHT NORMALIZATION
- ▲ FINE-GRAIN NORMALIZATION
- X 1/2 DETECTION LIMIT
- * SURFACE WATER RUNON LOCATION

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**IRON CONCENTRATIONS FOR
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SAMPLES (WET SEASON, JANUARY 1992)**

916055.24/P2SK043

FIGURE SW-25

Location 2530. Except for the sample collected from Location 2530, dry weight concentrations of iron were typically detected in a range of 10,000 mg/kg to 30,000 mg/kg and were fairly uniform throughout all reaches. When normalized to percent fine-grain material, concentrations of iron followed a pattern similar to those discussed for copper and total chromium.

Iron was detected in all onsite sediment samples collected during the wet season. Concentrations ranged from 4,330 mg/kg at Location 2516 to 105,000 mg/kg at Location 2530. Dry weight concentrations were relatively constant, except for the concentration detected in the sample collected from Location 2530. When normalized to percent fine-grain material, the most elevated concentrations were detected in samples collected from Reach A. Normalized concentrations generally decreased from this reach.

Maximum iron concentrations were approximately two to four times greater in wet season sediment samples than in the dry or transitional season sediment samples.

5.1.13.5 Runoff. Iron was detected in all biweekly surface water and stormwater runoff samples collected from Location 2515. The biweekly surface water runoff concentrations ranged from 1,040 $\mu\text{g/L}$ to 2,610 $\mu\text{g/L}$ (see Table SW-9). The stormwater runoff concentration was 1,290 $\mu\text{g/L}$. Runoff iron concentrations were within the range of runoff concentrations and less than concentrations detected in the Leach Creek Area (Lum and Turney 1988b).

5.1.14 Lead

Lead is a naturally occurring metal that is released to the environment by both natural and anthropogenic processes. Concentrations of lead in surface waters typically range between 5 and 30 $\mu\text{g/L}$ (ATSDR 1988b). In the vicinity of STF, concentrations of lead were below 25 $\mu\text{g/L}$ in samples collected in the Leach Creek area in January 1983 (Lum and Turney 1985).

Lead is largely detected in association with suspended solids and sediment in aquatic systems. Sediment contains considerably higher levels of lead than corresponding surface water due to adsorption and co-precipitation (Hem 1989). River sediment is estimated to contain approximately 20 mg/kg and coastal sediment contains approximately 100 mg/kg. Lead concentrations in the sediment in the Leach Creek area ranged from 20 to 580 mg/kg (Lum and Turney 1985).

5.1.14.1 Background. Lead was detected in background samples collected during the dry season event at Locations 2500 (19.3 $\mu\text{g/L}$), 2541 (13.6 $\mu\text{g/L}$), and 2543 (8.4 $\mu\text{g/L}$) (see Table SW-6). Lead was not detected in samples collected from background locations during the wet season event. AFWQC for lead was not exceeded in background dry season samples. Lead concentrations were higher in dry season background surface water samples than wet season.

5.1.14.2 Runon. Lead was detected in all runon samples collected at both locations. Monthly runon surface water concentrations ranged from undetected to 77.7 $\mu\text{g/L}$ at Location 2500 and ranged from undetected to 40.9 $\mu\text{g/L}$ at Location 2501 (see Table SW-7). The stormwater runon concentrations ranged from 15.6 $\mu\text{g/L}$ to 95.6 $\mu\text{g/L}$ at Location 2500 and from 16.3 $\mu\text{g/L}$ to 124 $\mu\text{g/L}$ at Location 2501. The 1-hour average WQC was exceeded for one monthly runon concentration at each location (2500 and 2501). The 1-hour average WQC was exceeded for 9 and 10 storm event concentrations at Locations 2500 and 2501, respectively.

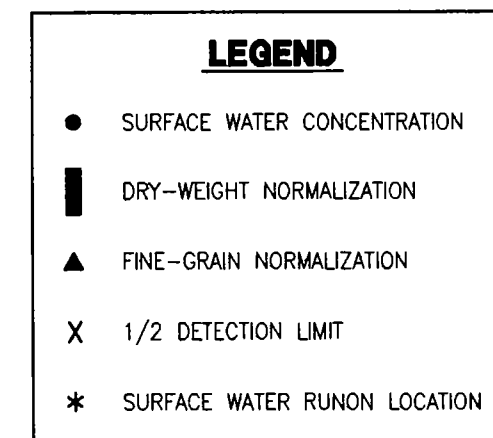
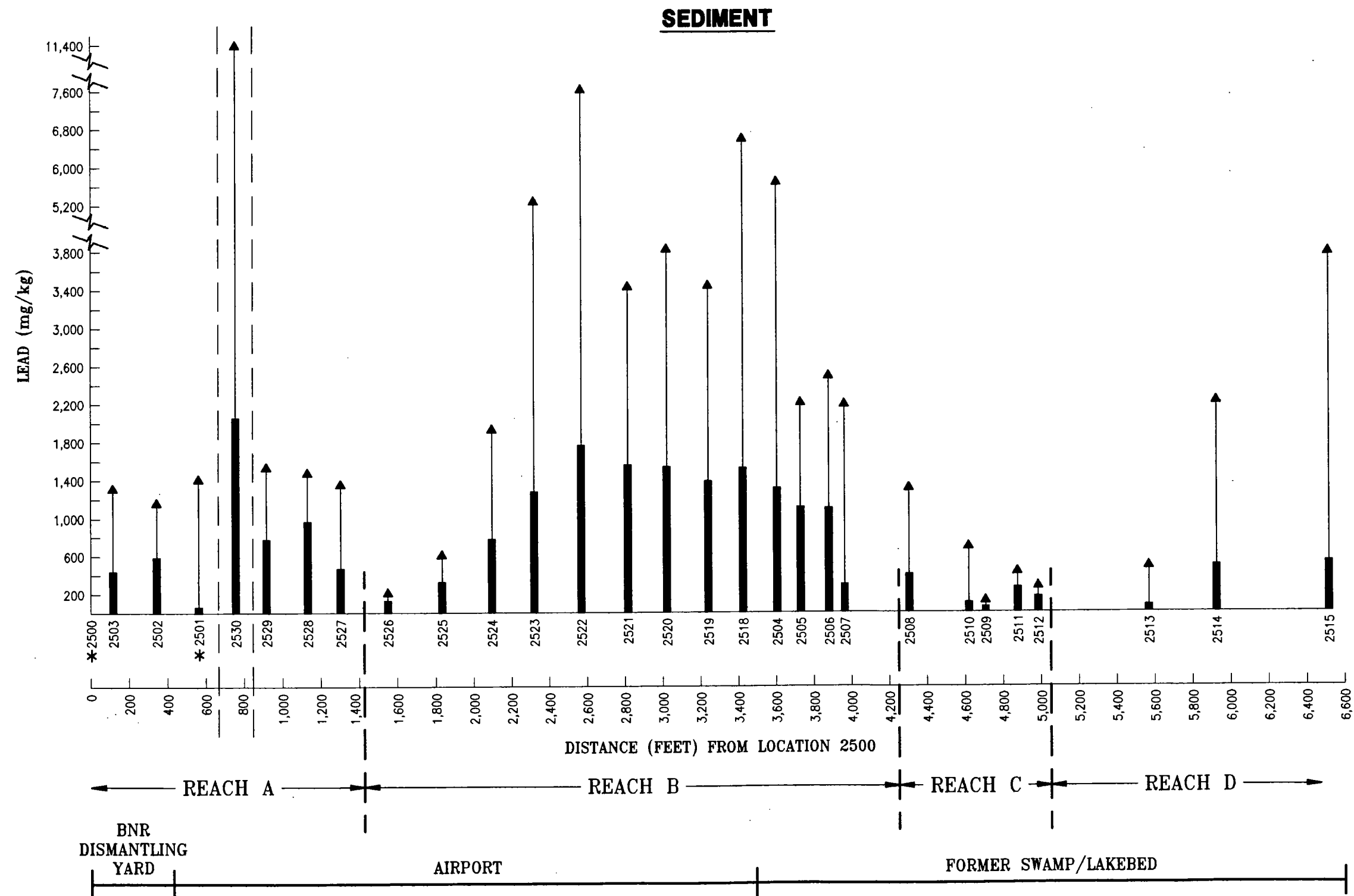
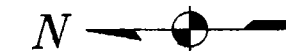
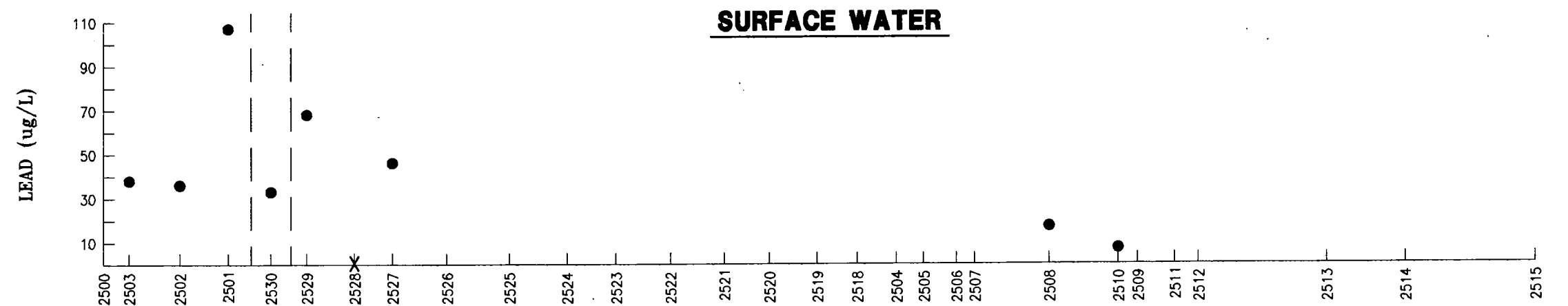
Generally, lead concentrations in stormwater runon were higher than concentrations in monthly runon at both locations (see Appendix SW-B). The runon monthly and stormwater concentrations were slightly higher at Location 2501 than at Location 2500. Seasonal variations were apparent with lead concentrations increasing during the months of July to October at both locations. The one exception is the high concentration of lead detected in the samples collected during the 100 year storm on 4 April 1991.

Lead was detected at monthly runoff concentrations which exceeded the background surface water range at Locations 2500 (3 exceedances) and 2501 (2 exceedances). Lead was detected at storm event concentrations which exceeded the background surface water range at Locations 2500 (8 exceedances) and 2501 (9 exceedances). In addition, the detected lead concentrations were greater than typical surface water concentrations and greater than the lead concentrations detected in the vicinity of STF.

5.1.14.3 Onsite Surface Water. Concentrations of lead in onsite surface water and sediment samples collected during the transitional season are presented in Appendix SW-D. Lead was detected in only one surface water sample (8.3 $\mu\text{g/L}$ at Location 2509) collected during the transitional season (see Table SW-8). This concentration did not exceed the maximum runoff concentration for lead of 124 $\mu\text{g/L}$. The maximum AFWQC for lead (53.4 $\mu\text{g/L}$) was not exceeded.

Concentrations of lead in onsite surface water and sediment samples collected during the dry season are presented in Appendix SW-D and Figure SW-26. Lead was detected in all but one surface water sample; most detected concentrations were from samples collected from Reach A. Concentrations ranged from undetected to 107 $\mu\text{g/L}$ at Location 2501. No detected concentrations exceeded the maximum runoff surface water concentration of 124 $\mu\text{g/L}$. The AFWQC for lead was exceeded at Location 2501 and 2529.

Concentrations of lead in onsite surface water and sediment samples collected during the wet season are presented in Appendix SW-D and Figure SW-27. Lead was detected in all but two wet season surface water samples. Concentrations ranged from undetected to 219 $\mu\text{g/L}$ at Location 2527. Onsite surface water data show a concentration pattern similar to those for previously described inorganics (i.e., concentrations were the most elevated in Reach B, but were considerably lower in Reaches A and C). Two concentrations associated with the samples collected from Locations 2520 and 2527 exceeded the maximum runoff surface



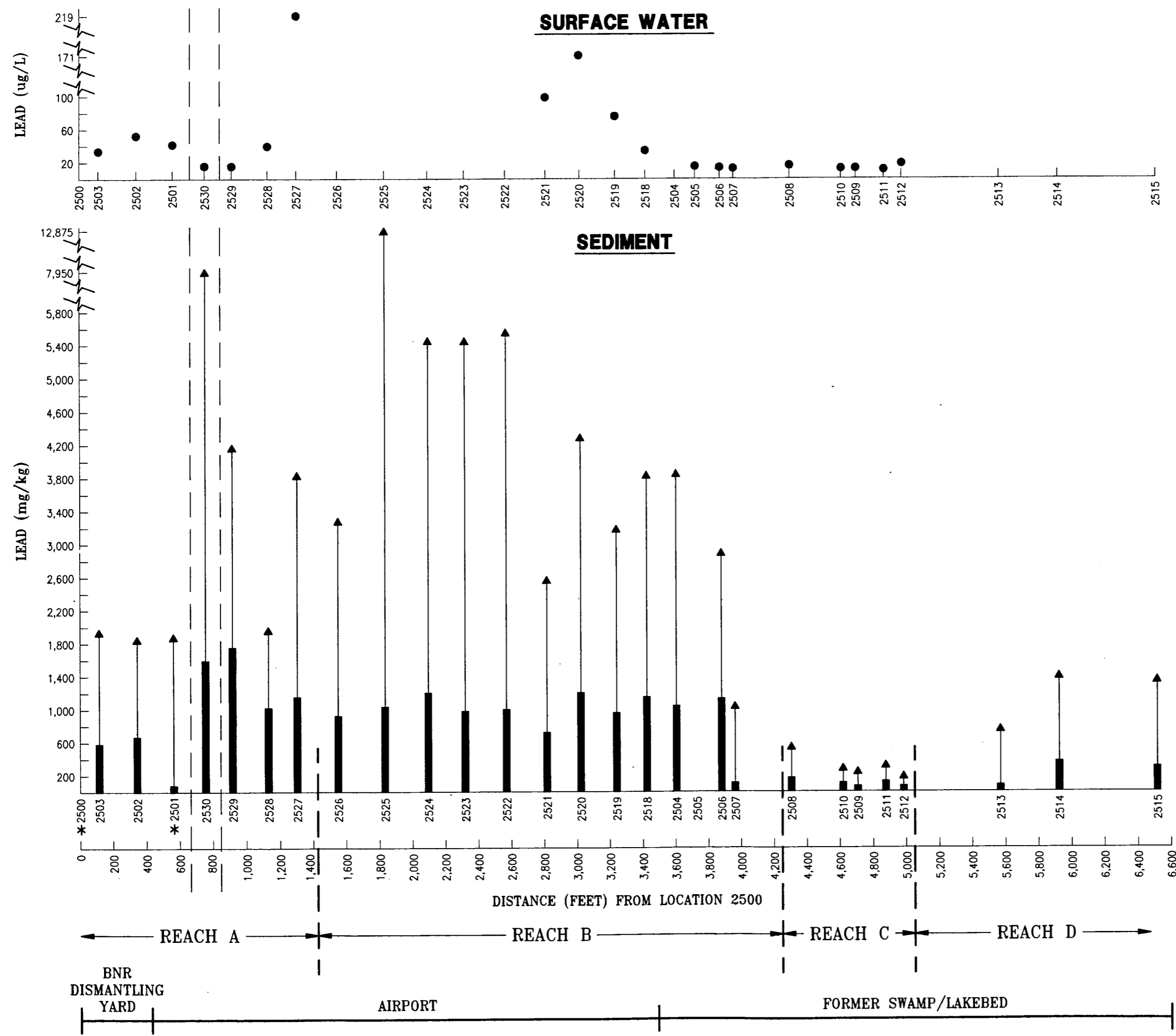
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SOUTH TACOMA FIELD
TACOMA, WA

**LEAD CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (DRY SEASON, AUGUST 1991)**

916055.24/P2SK011

FIGURE SW-26



LEGEND

- SURFACE WATER CONCENTRATION
- DRY-WEIGHT NORMALIZATION
- ▲ FINE-GRAIN NORMALIZATION
- X 1/2 DETECTION LIMIT
- * SURFACE WATER RUNON LOCATION

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SOUTH TACOMA FIELD
TACOMA, WA

**LEAD CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (WET SEASON, JANUARY 1992)**

916055.24/P2SK044

FIGURE SW-27

water concentration. Nine concentrations exceeded the AFWQC (22.2 $\mu\text{g/L}$) for lead.

Maximum lead concentrations were 2 to more than 20 times greater in the wet season surface water samples compared to the dry and transitional season samples. Six of the dry season and nine of the wet season onsite surface water lead concentrations were greater than typical concentrations in surface water and those detected in the Leach Creek area.

5.1.14.4 Onsite Sediment. Lead was detected in all onsite sediment samples collected during the transitional season. Concentrations ranged from 13.8 mg/kg at Location 2516 to 170.0 mg/kg at Location 2506.

Lead was detected in all sediment samples collected during the dry season. Concentrations ranged from 4.0 mg/kg at Location 2509 to 2,050 mg/kg at Location 2530. Most elevated concentrations (on a dry weight basis) of lead were detected in Reach B (except for the maximum concentration which was detected in Reach A). When normalized to percent fine-grain material, most of the normalized concentrations were detected in samples collected from Reach B with the maximum normalized concentration detected in the sample from Reach A.

Lead was detected in all onsite sediment samples collected during the wet season. Concentrations ranged from 11.3 mg/kg at Location 2516 to 1,750 mg/kg at Location 2529. Dry weight concentrations of lead were the most elevated in the southern section of Reach A and throughout most of Reach B. Concentrations were at much lower levels in samples collected from Reaches C and D compared to concentrations in samples from Reach B. When normalized to percent fine-grain material, concentrations were similar to those reported for samples evaluated on a dry weight basis (i.e., normalized concentrations were more elevated in the southern section of Reach A and throughout Reach B and then decreased significantly in Reaches C and D).

Maximum onsite sediment lead concentrations were approximately equivalent in the dry and wet seasons. These concentrations were approximately 1 order of magnitude greater than the transitional season maximum sediment concentration. The maximum onsite sediment lead concentrations were also greater than Leach Creek area sediment concentrations.

5.1.14.5 Runoff. Lead was detected in all biweekly surface water runoff samples collected from Location 2515. The biweekly surface water runoff concentration ranged from 2.7 $\mu\text{g/L}$ (below CRDL) to 9.5 $\mu\text{g/L}$. All the detected concentrations were below the AFWQC. Runoff lead concentrations were within the range of runoff concentrations, within surface water concentrations typical to surface waters nationally, and within the Leach Creek area.

5.1.15 Magnesium

5.1.15.1 Background. Magnesium was detected in all of the background samples. Dry season event background concentrations of magnesium ranged from 949 $\mu\text{g/L}$ (below CRDL) to 39,900 $\mu\text{g/L}$ (see Table SW-6). Wet season event background concentrations of magnesium ranged from 687 $\mu\text{g/L}$ (below CRDL) to 33,600 $\mu\text{g/L}$. EPA has not proposed WQC for magnesium. The dry season background concentration of magnesium were detected at slightly higher concentrations than those detected in the wet season samples (except for Location 2500).

5.1.15.2 Runon. Magnesium was detected in runoff surface water samples collected at both locations. The monthly runoff concentrations ranged from 1,340 $\mu\text{g/L}$ (below CRDL) to 13,700 $\mu\text{g/L}$ at Location 2500 and ranged from 1,210 $\mu\text{g/L}$ (below CRDL) to 8,710 $\mu\text{g/L}$ at Location 2501 (see Table SW-7). The stormwater runoff concentration for magnesium ranged from 758 $\mu\text{g/L}$ (below CRDL) to 3110 $\mu\text{g/L}$ at Location 2500 and from 1,570 $\mu\text{g/L}$ (below CRDL) to 8,260 $\mu\text{g/L}$ at Location 2501.

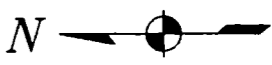
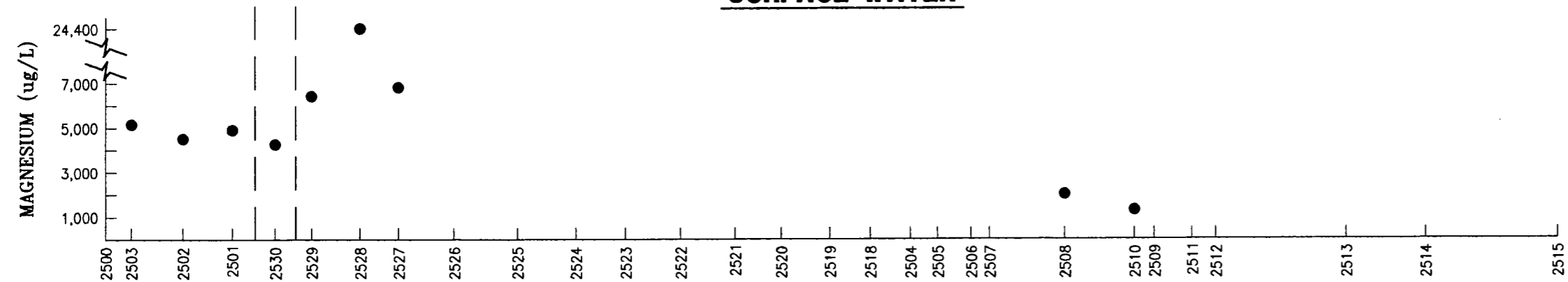
Generally, magnesium concentrations in monthly runon were higher than concentrations in stormwater runon at Location 2500 (see Appendix SW-B). The runon monthly concentrations were slightly higher at Location 2500 than at Location 2501. However, the runon stormwater concentrations detected at Location 2500 were consistently lower than the concentrations detected at Location 2501. Seasonal variations were apparent with magnesium concentrations increasing during the months of October and November at Location 2501. The one exception is the high concentrations of magnesium detected in the samples collected during the 100 year storm on 4 April 1991. The monthly and storm event concentrations were within the background surface water range.

5.1.15.3 Onsite Surface Water. Concentrations of magnesium in onsite surface water and sediment samples collected during the transitional season (April 1991) are presented in Appendix SW-D. Magnesium was detected in all onsite surface water samples collected during the transitional season. Concentrations ranged from 1,720 $\mu\text{g/L}$ (concentration is below CRDL) at Location 2511 to 10,100 $\mu\text{g/L}$ at Location 2516 (see Table SW-8). Most detected concentrations were below the CRDL. No concentrations exceeded the maximum runon concentration of 13,700 $\mu\text{g/L}$.

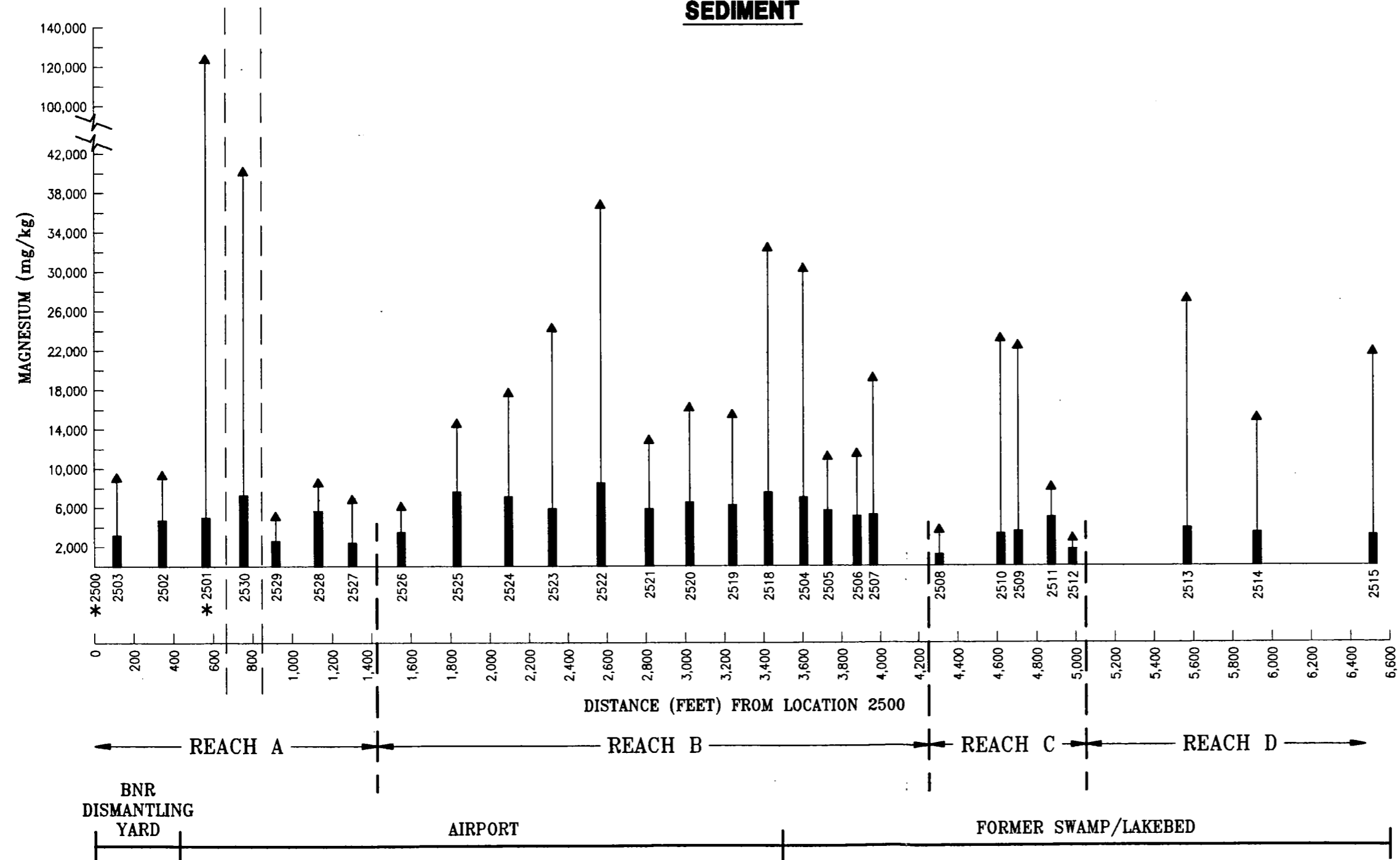
Concentrations of magnesium in onsite surface water and sediment samples collected during the dry season are presented in Appendix SW-D and Figure SW-28. Concentrations in onsite surface water samples ranged from 1,290 $\mu\text{g/L}$ (below CRDL) at Location 2510 to 24,400 $\mu\text{g/L}$ at Location 2528 (see Table SW-8). Concentrations were fairly constant in the northern section of Reach A before increasing from Location 2530 to Location 2528 and then declining. All concentrations were below the maximum runon surface water concentration, except the sample collected from Location 2528.

Concentrations of magnesium in onsite surface water and sediment samples collected during the wet season are presented in Appendix SW-D and Figure SW-29. Magnesium was detected in all onsite surface water samples collected

SURFACE WATER



SEDIMENT



LEGEND

- SURFACE WATER CONCENTRATION
- DRY-WEIGHT NORMALIZATION
- ▲ FINE-GRAIN NORMALIZATION
- X 1/2 DETECTION LIMIT
- * SURFACE WATER RUNON LOCATION

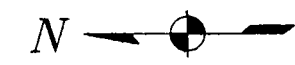
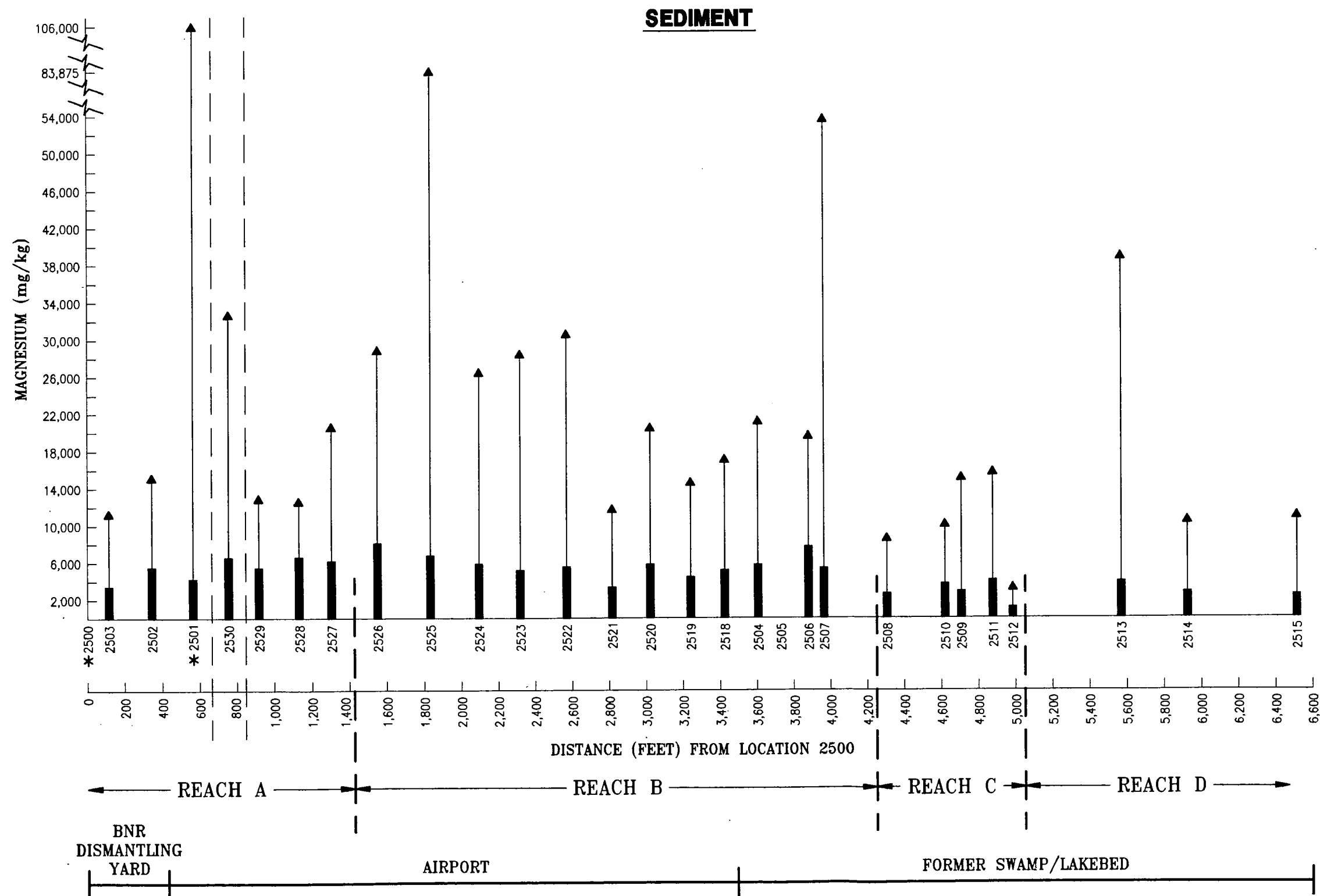
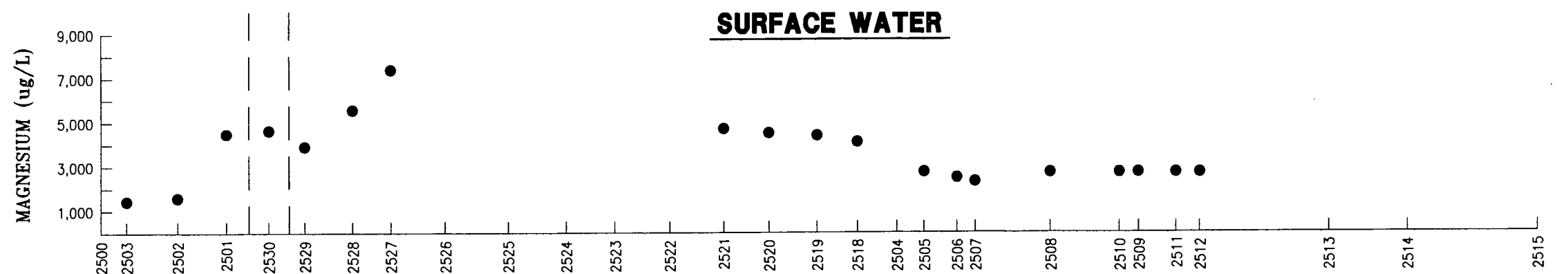
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SOUTH TACOMA FIELD
TACOMA, WA

**MAGNESIUM CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (DRY SEASON, AUGUST 1991)**

916055.24/P2SK020

FIGURE SW-28



LEGEND

- SURFACE WATER CONCENTRATION
- DRY-WEIGHT NORMALIZATION
- ▲ FINE-GRAIN NORMALIZATION
- X 1/2 DETECTION LIMIT
- * SURFACE WATER RUNON LOCATION

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SOUTH TACOMA FIELD
TACOMA, WA

**MAGNESIUM CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (WET SEASON, JANUARY 1992)**

916055.24/P2SK045

FIGURE SW-29

during the wet season. Concentrations, most of which were below the CRDL, ranged from 1,430 $\mu\text{g/L}$ at Location 2503 to 7,350 $\mu\text{g/L}$ at Location 2527.

Concentrations exhibited a pattern similar to that described for previous inorganic surface water samples collected in the wet season. No concentrations exceeded the maximum runoff surface water concentration. Maximum magnesium concentrations were similar for all seasonal onsite surface water samples.

5.1.15.4 Onsite Sediment. Magnesium was detected in all onsite sediment samples collected during the transitional season. Concentrations ranged from 3,490 mg/kg at Location 2516 to 4,910 mg/kg at Location 2506.

Magnesium was detected in all onsite sediment samples collected during the dry season. Concentrations ranged from 1,110 mg/kg (below CRDL) at Location 2508 to 8,470 mg/kg at Location 2522. The most elevated concentrations, measured on a dry weight basis, were associated with samples collected from Reach B and in the sample collected from Location 2530 in Reach A. When normalized to percent fine-grain material, the pattern of concentrations of magnesium are similar to the patterns described for cobalt, total chromium, and iron.

Magnesium was detected in all onsite sediment samples collected during the wet season. Concentrations ranged from 1,120 mg/kg (concentration is below the CRDL) at Location 2512 to 8,090 mg/kg at Location 2526. Dry weight concentrations were relatively constant in Reaches A and B, but declined slightly in Reaches C and D. When normalized to percent fine-grain material, elevated peaks were shown in Reach A (Location 2501), Reach B (locations 2525 and 2507), and in Reach D (Location 2513). The percent fine-grain material at these locations was very low (between 4 and 10 percent). Maximum magnesium concentrations were similar for all seasonal onsite sediment samples.

5.1.15.5 Runoff. Magnesium was detected in all biweekly surface water and stormwater runoff samples collected from Location 2515. The biweekly surface

water runoff concentrations ranged from 1,230 $\mu\text{g/L}$ to 1,910 $\mu\text{g/L}$ (all below CRDL) (see Table SW-9). The stormwater runoff concentration was 2,170 $\mu\text{g/L}$ (below CRDL), which is greater than all the biweekly surface water runoff concentrations. Runoff magnesium concentrations were within the range of runoff concentrations.

5.1.16 Manganese

Manganese in decaying plant matter generally becomes available for dissolution into runoff. Thin coatings of manganese oxides in streambeds occur in many places which may or may not be associated with organic intervention. The USGS suggested that high manganese concentration in the Puget Sound region were probably naturally occurring. In the vicinity of STF, concentrations of manganese in surface waters were detected above 4,000 $\mu\text{g/L}$ in the Leach Creek area in January 1983 (Lum and Turney 1985). Manganese in surface waters may oxidize or adsorb to sediment particles and settle out, or be transported as suspended sediment (ATSDR 1990e).

5.1.16.1 Background. Manganese was detected in all but one of the background samples. Dry season event background concentrations of manganese ranged from 27.3 $\mu\text{g/L}$ to 1,820 $\mu\text{g/L}$ (see Table SW-6). Manganese was detected in samples collected during the wet season event at all background locations except Location 2500. Wet season event background concentrations of manganese ranged from undetected to 1,440 $\mu\text{g/L}$. EPA has not proposed WQC for manganese. At all background locations, the dry season concentrations were detected at values higher than those detected in the wet season samples.

5.1.16.2 Runon. Manganese was detected in runoff surface water samples collected at both locations. The monthly runoff concentrations ranged from undetected to 121 $\mu\text{g/L}$ at Location 2500 and ranged from undetected to 659 $\mu\text{g/L}$ at Location 2501 (see Table SW-7). The stormwater runoff concentration for

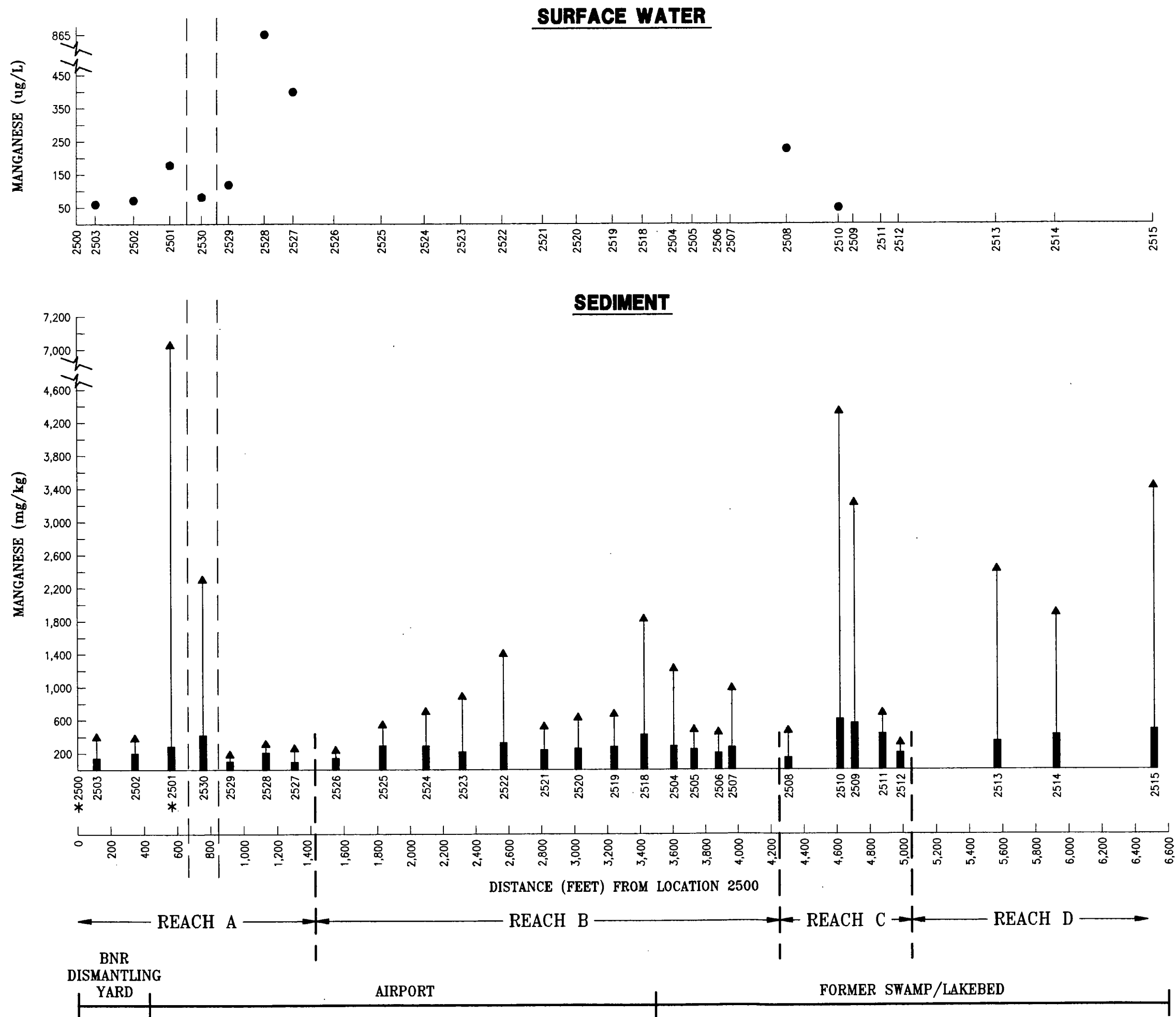
manganese ranged from 19.9 $\mu\text{g/L}$ to 113 $\mu\text{g/L}$ at Location 2500 and ranged from 186 $\mu\text{g/L}$ to 453 $\mu\text{g/L}$ at Location 2501.

Generally, manganese concentrations in stormwater runon were higher than concentrations in monthly runon at both locations (see Appendix SW-B). The concentrations detected in runon samples (stormwater and monthly) collected at Location 2501 were higher than the concentrations detected in samples collected at Location 2500. Seasonal variations were apparent with manganese concentrations increasing during the months of July to October at Location 2500 and during the months of June to December at Location 2501. The one exception is the high concentrations of manganese detected in the samples collected during the 100-year storm on 4 April 1991.

The manganese monthly and stormwater runon concentrations were within the background surface water range. Higher concentrations of manganese are reported as naturally occurring. The range of manganese concentrations detected at locations 2500 and 2501 were lower than the concentrations detected in the USGS study.

5.1.16.3 Onsite Surface Water. Concentrations of manganese in onsite surface water and sediment samples collected during the transitional season are presented in Appendix SW-D. Onsite surface water concentrations ranged from undetected to 711 $\mu\text{g/L}$ at Location 2516 (see Table SW-8). The concentration associated with the sample collected from Location 2516 exceeded the maximum runon surface water concentration of 659 $\mu\text{g/L}$.

Concentrations of manganese in onsite surface water and sediment samples collected during the dry season are presented in Appendix SW-D and Figure SW-30. Manganese was detected in all surface water samples collected during the dry season. Concentrations ranged from 46.4 $\mu\text{g/L}$ at Location 2510 to 865 $\mu\text{g/L}$ at Location 2528. The most elevated concentrations were detected in the surface water samples collected from the southern section of Reach A. All concentrations,



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916055.24/P2SK021

FIGURE SW-30

except for the concentration associated with the sample collected from Location 2528, were below the maximum runoff surface water concentration.

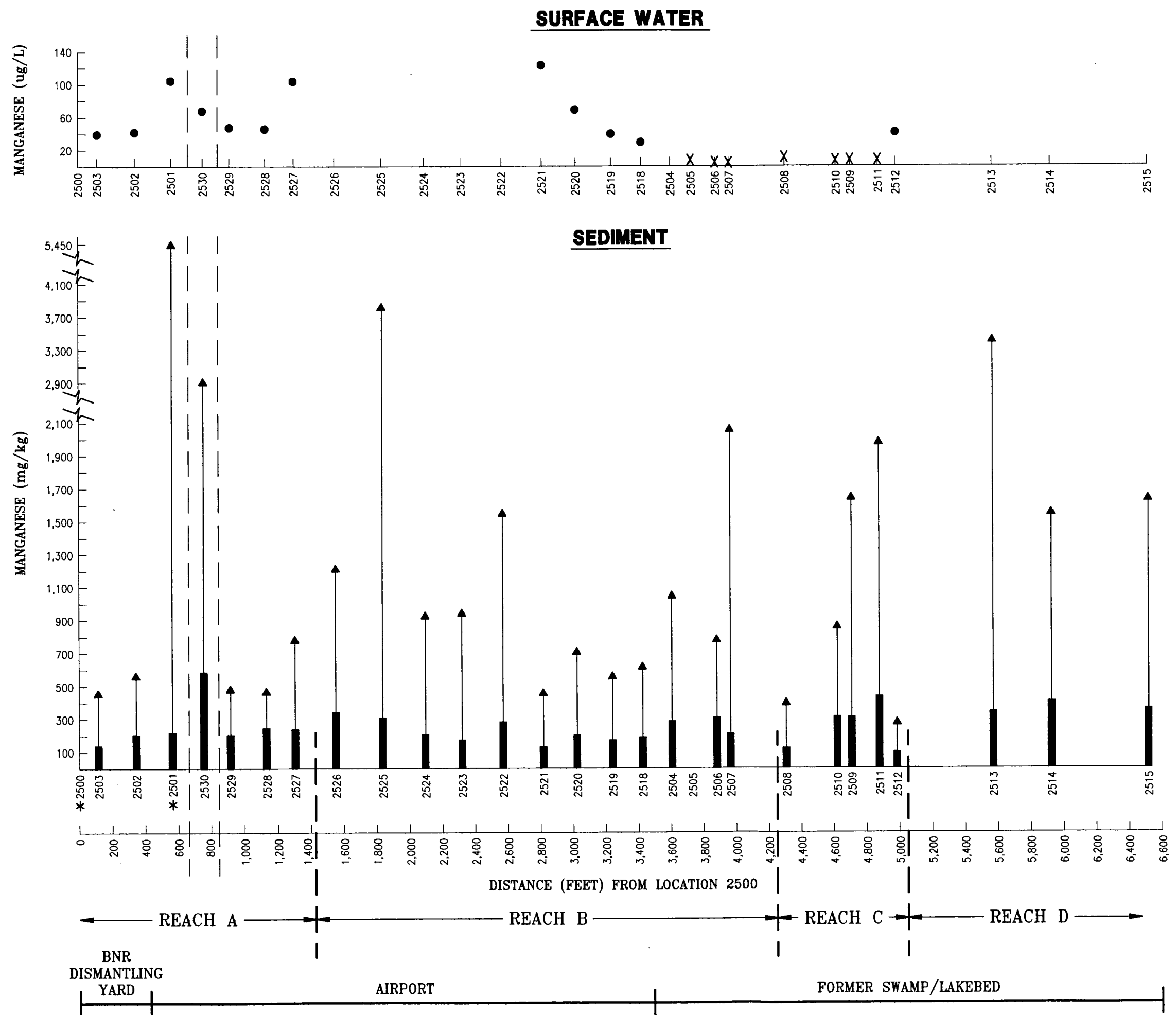
Concentrations of manganese in onsite surface water and sediment samples collected during the wet season are presented in Appendix SW-D and Figure SW-31. Manganese was detected in 14 out of 24 surface water samples collected during the wet season. Concentrations ranged from undetected to 132 $\mu\text{g/L}$ at Location 2516. When graphically presented, concentrations exhibited a pattern similar to that described for other inorganics. No concentrations exceeded the maximum runoff surface water concentration for manganese.

Maximum onsite surface water manganese concentrations were similar in the transitional and dry seasons. These concentrations were approximately five to six times greater than the wet season maximum concentration. The range of manganese concentrations were within the range of concentrations detected in the USGS study.

5.1.16.4 Onsite Sediment. Manganese was detected at estimated concentrations in all sediment samples collected during the transition season. Concentrations ranged from 206 mg/kg at Location 2516 to 473 mg/kg at Location 2509.

Manganese was detected in all onsite sediment samples collected during the dry season. Concentrations ranged from 89.9 mg/kg at Location 2527 to 814 mg/kg at Location 2509. Concentrations, measured on a dry weight basis, did not show any discernible trends, although the most elevated concentrations were detected in samples collected from Reach C. When normalized to percent fine-grain material, sample locations with low amounts of fine-grain material (less than 20 percent) exhibited the highest normalized concentrations (e.g., locations 2501, 2510, 2509, and 2515).

Manganese was detected in all onsite sediment samples collected during the wet season. Concentrations ranged from 67.6 mg/kg at Location 2516 to 615 mg/kg at



LEGEND

- SURFACE WATER CONCENTRATION
- DRY-WEIGHT NORMALIZATION
- ▲ FINE-GRAIN NORMALIZATION
- X 1/2 DETECTION LIMIT
- * SURFACE WATER RUNON LOCATION

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**MANGANESE CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (WET SEASON, JANUARY 1992)**

916055.24/P2SK046

FIGURE SW-31

Location 2511. Dry weight concentrations were fairly constant throughout most of Reaches A, B, and C, although a few location exhibited elevated concentrations (Location 2530 in Reach A) and Location 2511 in Reach C). Reach D exhibited relatively elevated concentrations for all samples collected in that reach. When normalized to percent fine-grain material, elevated concentrations were detected in locations where the percent fine-grain material was very low (4-10 percent) except at Location 2511, where the percent fine-grain material was 32. The elevated normalized concentration at this sampling location may be explained by noting that the sample exhibited the maximum concentration.

Maximum manganese concentrations were approximately similar for all seasonal onsite sediment samples.

5.1.16.5 Runoff. Manganese was detected in all biweekly surface water and stormwater runoff samples collected from Location 2515. The biweekly surface water runoff concentration ranged from 21.1 $\mu\text{g/L}$ to 52.6 $\mu\text{g/L}$ (see Table SW-9). The stormwater runoff concentration was 29.0 $\mu\text{g/L}$. Runoff concentrations were within the range of runoff concentrations and below concentrations detected in the Leach Creek area.

5.1.17 Mercury

Mercury is released into the environment by both natural processes and anthropogenic sources (ATSDR 1988c). Concentrations of mercury in natural river water are typically very small ($<0.3 \mu\text{g/L}$) (Hem 1989). In the vicinity of STF, concentrations of mercury were detected below $0.5 \mu\text{g/L}$ in the Leach Creek area in January 1983 (Lum and Turney 1985). Inorganic mercury tends to sorb to particulate matter that settle in the sediments (ATSDR 1988c). Mercury concentrations detected in Leach Creek sediment were reported to range from 0.030 mg/kg to 2.4 mg/kg (Lum and Turney 1985).

Mercury was not detected in any background or runoff surface water samples (see Table SW-6).

5.1.17.1 Runon. Mercury was detected in runon samples collected from both locations. Mercury was detected in only one stormwater runon sample ($0.25 \mu\text{g/L}$) collected at Location 2500. Two stormwater runon concentrations of mercury were detected [$0.14 \mu\text{g/L}$ (below CRDL) to $0.31 \mu\text{g/L}$] at Location 2501. AFWQC for mercury were not exceeded.

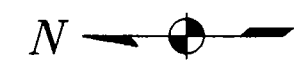
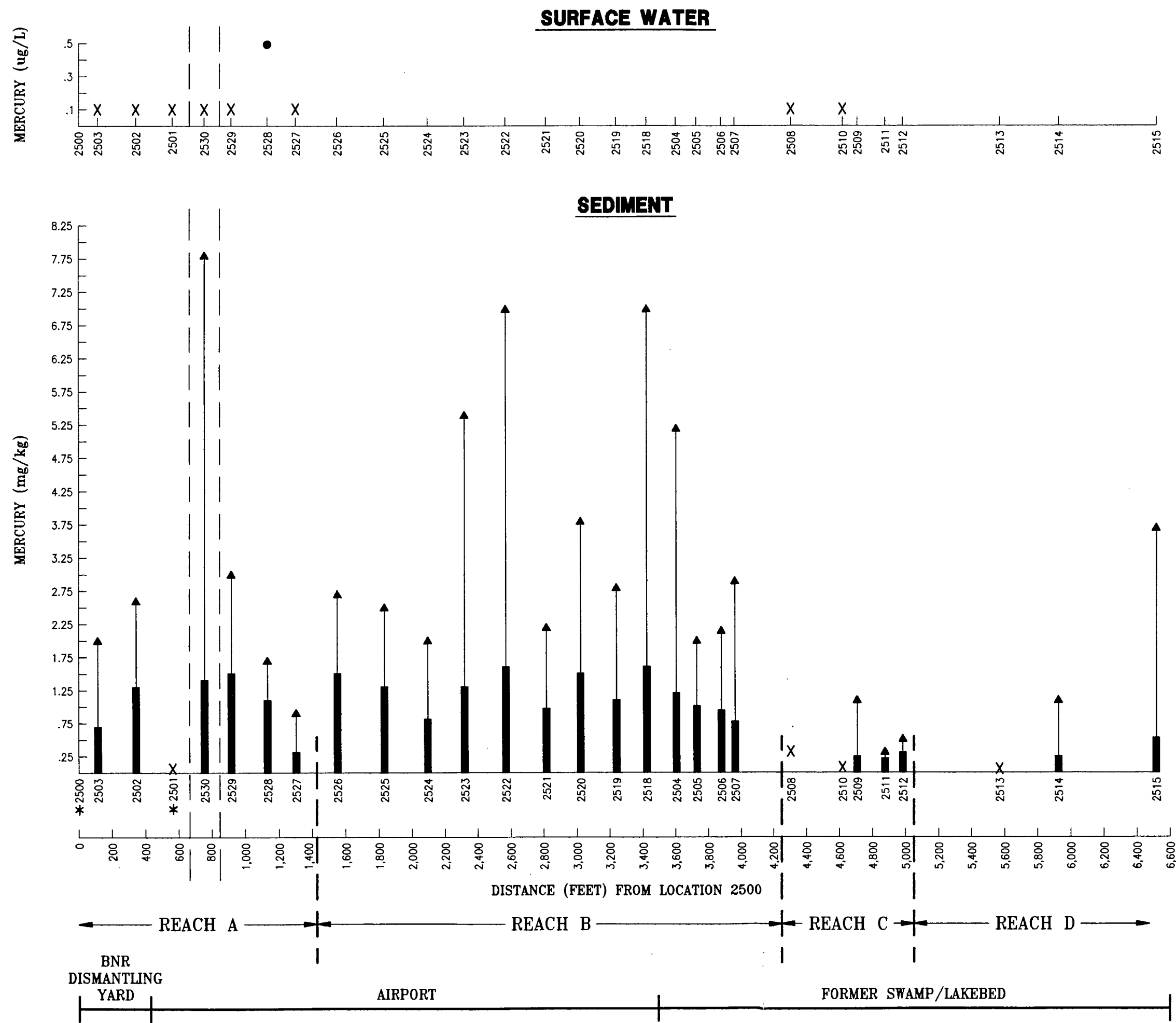
The concentrations detected in runon samples (stormwater) collected at Location 2501 were similar to the concentrations detected in samples collected at Location 2500 (see Appendix SW-B).

The two stormwater runon concentrations detected exceeded the background surface water range at locations 2500 and 2501. The mercury concentrations detected in the runon samples at both locations were similar to concentrations typically detected in river waters and in the vicinity of STF.

5.1.17.2 Onsite Surface Water. Concentrations of mercury in onsite surface water and sediment samples collected during the transitional season are presented in Appendix SW-D. Mercury was detected in only one surface water sample collected during the transitional season. Mercury was detected at $0.10 \mu\text{g/L}$ at Location 2509. This concentration is below the CRDL, the maximum runon surface water concentration ($0.43 \mu\text{g/L}$), and the AFWQC ($2.4 \mu\text{g/L}$) for mercury.

Concentrations of mercury in onsite surface water and sediment samples collected during the dry season are presented in Appendix SW-D and Figure SW-32.

Mercury was detected in only one surface water sample ($0.49 \mu\text{g/L}$ at Location 2528) collected during the dry season. This concentration exceeded the maximum runon surface water concentration. The detected concentration is below the AFWQC.



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SOUTH TACOMA FIELD
TACOMA, WA

**MERCURY CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (DRY SEASON, AUGUST 1991)**

916055.24/P2SK022

FIGURE SW-32

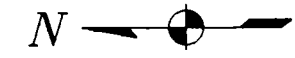
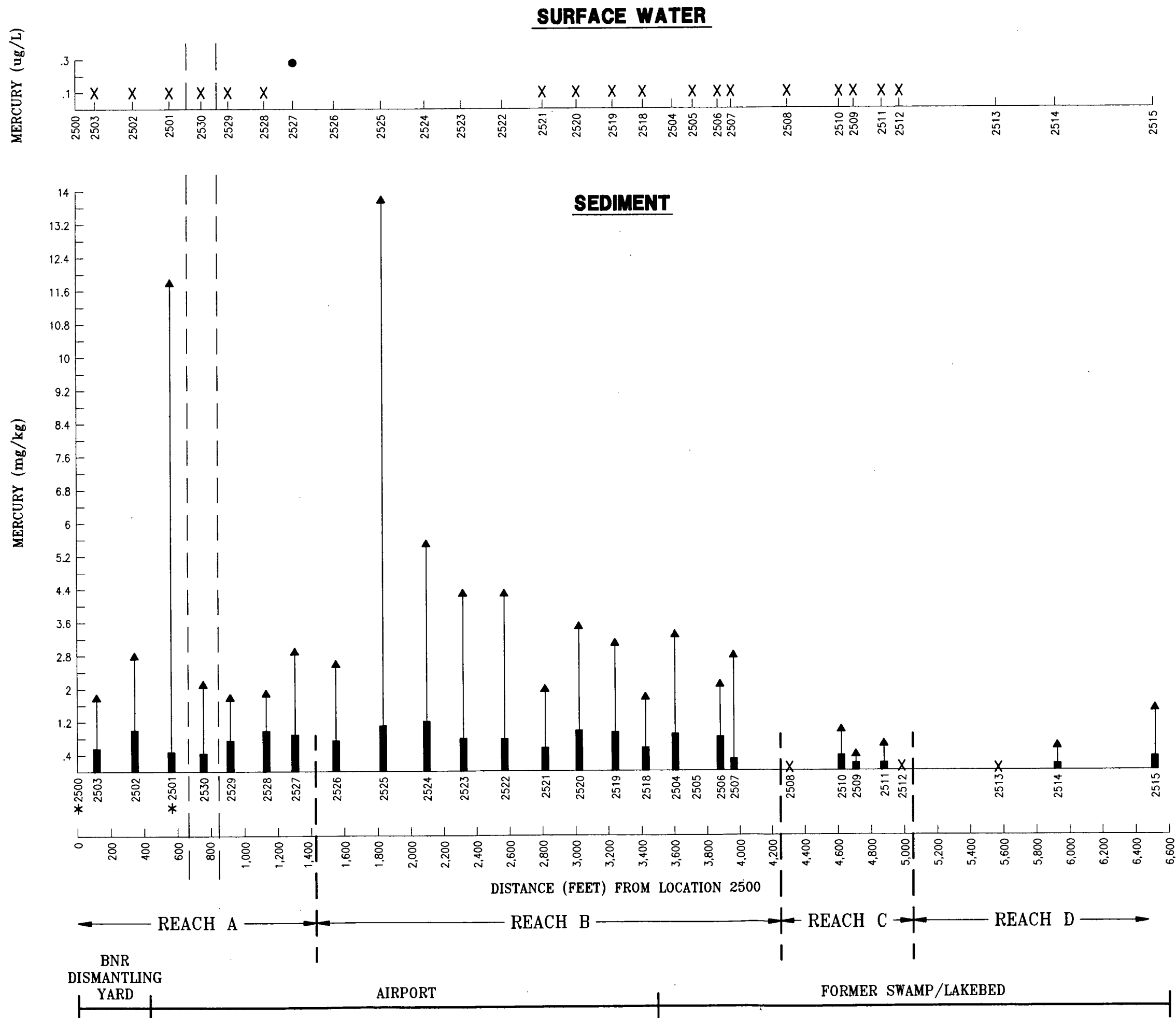
Concentrations of mercury in onsite surface water and sediment samples collected during the wet season (January 1992) from the surface water drainage channel are presented in Appendix SW-D and Figure SW-33. Mercury was detected in only one surface water sample (0.28 $\mu\text{g/L}$ at Location 2527). This concentration did not exceed the maximum runoff surface water concentration. The AFWQC for mercury (2.4 $\mu\text{g/L}$) was not exceeded at this location.

Maximum mercury concentrations were similar for the wet and dry season surface water samples. The onsite surface water mercury concentrations were also similar to concentrations typically detected in river waters and in the vicinity of STF.

5.1.17.3 Onsite Sediment. Mercury was detected in two of five sediment samples collected during the transitional season. The lowest concentration, 0.16 mg/kg, was detected in the sample collected from Location 2509. The highest concentration, 0.90 mg/kg, was detected in the sample collected from Location 2506.

Mercury was detected in most sediment samples collected during the dry season. Concentrations ranged from undetected to 1.6 mg/kg at locations 2518 and 2522. Concentrations, measured on a dry weight basis, were the most elevated in Reaches A and B, and were considerably lower in Reaches C and D. When normalized to percent fine-grain material, concentrations were the most elevated in Reaches A and B. Concentrations generally decreased in the southern end of Reach B and in all of Reach C before increasing in Reach D.

Mercury was detected in most sediment samples collected during the wet season. Concentrations ranged from undetected to 1.2 mg/kg at Location 2524. Dry weight concentrations did not vary significantly, although the most elevated concentrations were detected in samples collected from Reaches A and B. The lowest concentrations were detected in samples collected from Reaches C and D. When normalized to percent fine-grain material, mercury exhibited two elevated peaks at locations 2501 and 2525. Normalized concentrations decreased



LEGEND

- SURFACE WATER CONCENTRATION
- DRY-WEIGHT NORMALIZATION
- ▲ FINE-GRAIN NORMALIZATION
- X 1/2 DETECTION LIMIT
- * SURFACE WATER RUNON LOCATION

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SOUTH TACOMA FIELD
TACOMA, WA

**MERCURY CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (WET SEASON, JANUARY 1992)**

916055.24/P2SK047

FIGURE SW-33

immediately after Location 2525 and decreased throughout the remainder of the surface water channel.

Maximum mercury concentrations were equivalent for all seasonal sediment samples. All onsite sediment concentrations were within the reported Leach Creek sediment concentration range.

5.1.18 Nickel

Nickel is a transitional metal that occurs naturally in the environment with typical concentrations of 15 and 20 $\mu\text{g/L}$ in surface water (ATSDR 1987k). Greater amounts of nickel are potentially available from anthropogenic sources such as waste disposal (Hem 1989). In the vicinity of STF, concentrations of nickel were detected (less than 36 $\mu\text{g/L}$) in the Leach Creek area in January 1983. Nickel was detected at 194 $\mu\text{g/L}$ in a sample collected from a heavy flow of a leachate/runoff seep from a catch basin in the Leach Creek area in January 1983 (Lum and Turney 1985). Concentrations of nickel were detected in to range from 26 to 60 mg/kg in sediments sampled in the Leach Creek area (Lum and Turney 1985).

Nickel was not detected in any background samples (see Table SW-6).

5.1.18.1 Runon. Nickel was also not detected in monthly runon samples collected at Location 2500. Nickel concentrations ranging from undetected to 52.6 $\mu\text{g/L}$ were detected in monthly runon samples collected at Location 2501 (see Table SW-7). Nickel was detected (7.8 $\mu\text{g/L}$ below CRDL) in only one stormwater runon sample collected at Location 2500. The stormwater runon concentrations ranged from undetected to 49 $\mu\text{g/L}$ at Location 2501. The detected concentrations did not exceed AFWQC for nickel.

Stormwater runon concentrations were detected at higher values than the monthly runon concentrations at Location 2501 (see Appendix SW-B). Nickel was detected

at higher concentrations and more frequently at Location 2501 than Location 2500. No seasonal variation is present.

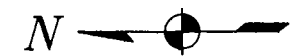
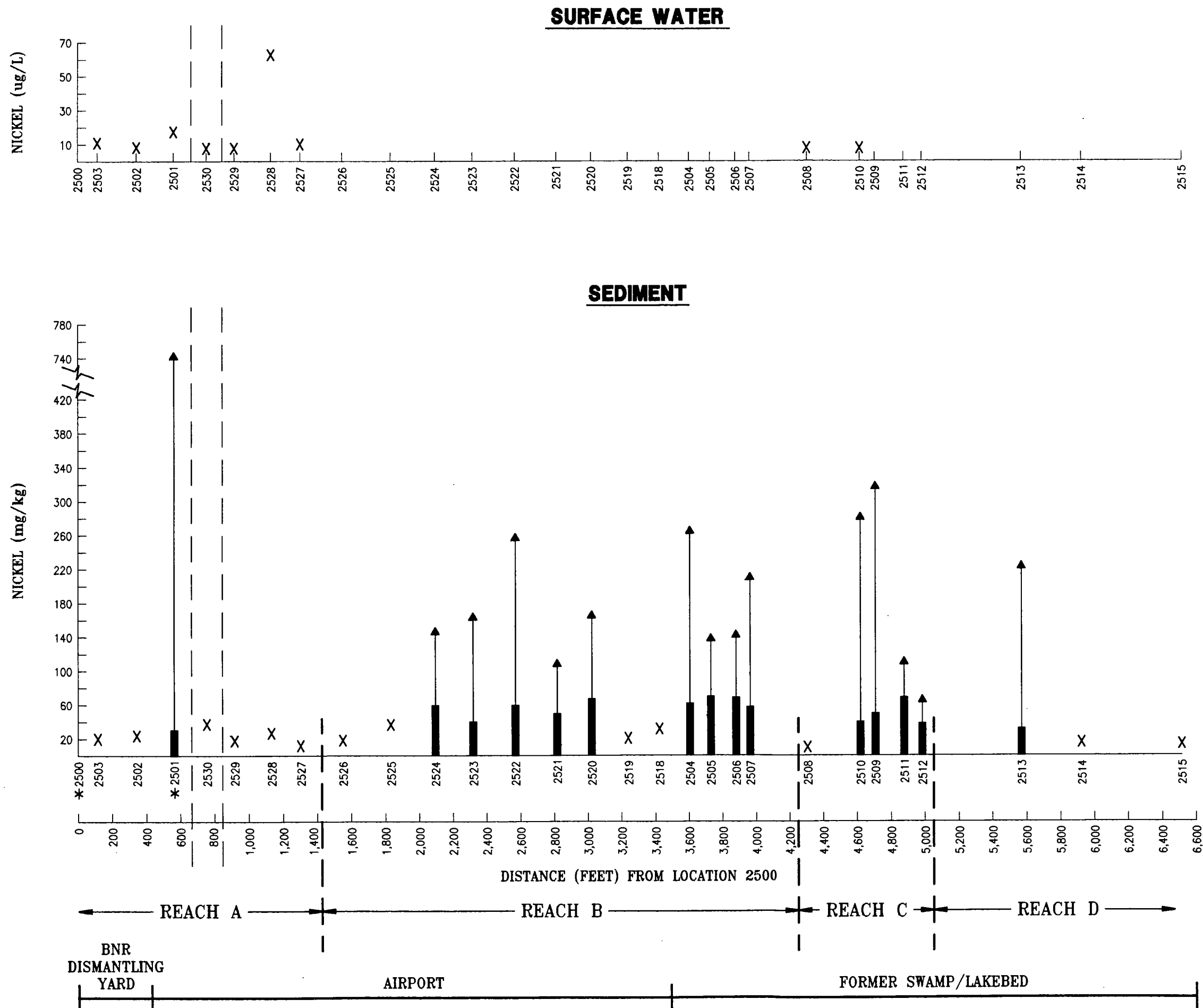
The monthly and stormwater runoff concentrations detected exceeded the background surface water range. The nickel concentrations detected at Location 2501 were greater than naturally occurring concentrations (15 to 20 $\mu\text{g/L}$). In the USGS study, Turney suggested that nickel concentrations detected in the vicinity of Leach Creek, which is the same range of concentrations as detected in the runoff samples, were evidence of anthropogenic sources in the area.

5.1.18.2 Onsite Surface Water. Concentrations of nickel in onsite surface water and sediment samples collected during the transitional season are presented in Appendix SW-D. Nickel was detected in three of the eight surface water samples collected during the transitional season. Concentrations (all of which were below CRDL), ranged from undetected to 9.9 $\mu\text{g/L}$ at Location 2516 (see Table SW-8). The AFWQC for nickel (1,069.6 $\mu\text{g/L}$) and the maximum runoff surface water concentration (52.6) were not exceeded at any location.

Concentrations of nickel in onsite surface water and sediment samples collected during the dry season are presented in Appendix SW-D and Figure SW-34. Nickel was not detected in onsite surface water samples collected during the dry season.

Concentrations of nickel in onsite surface water and sediment samples collected during the wet season are presented in Appendix SW-D and Figure SW-35. Nickel was detected at six of 24 surface water sample locations. Concentrations ranged from undetected to 18.4 $\mu\text{g/L}$ at Location 2521. Concentrations were generally higher in Reaches A and B compared to Reach C. The AFWQC for nickel (597.42 $\mu\text{g/L}$) was not exceeded at any location. No concentrations exceeded the maximum runoff surface water concentration.

Maximum surface water nickel concentrations were similar in the transitional and wet seasons. The onsite surface water nickel concentrations were similar to typical



LEGEND

- SURFACE WATER CONCENTRATION
- DRY-WEIGHT NORMALIZATION
- ▲ FINE-GRAIN NORMALIZATION
- X 1/2 DETECTION LIMIT
- * SURFACE WATER RUNON LOCATION

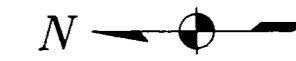
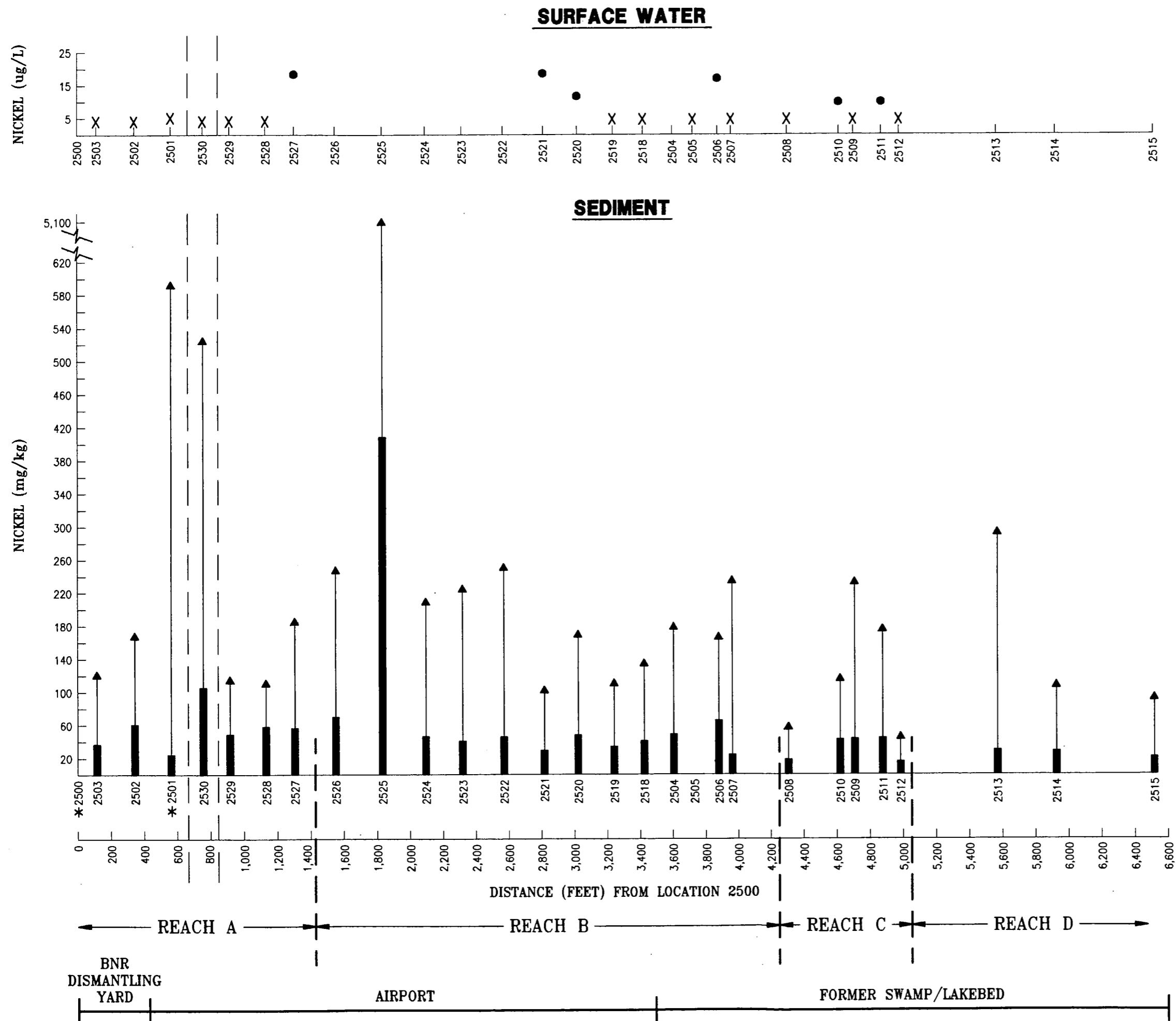
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SOUTH TACOMA FIELD
TACOMA, WA

**NICKEL CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (DRY SEASON, AUGUST 1991)**

916055.24/P2SK023

FIGURE SW-34



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SOUTH TACOMA FIELD
TACOMA, WA

**NICKEL CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (WET SEASON, JANUARY 1992)**

916055.24/P2SK048

FIGURE SW-35

concentrations detected in surface waters (15-20 $\mu\text{g/L}$) and to concentrations detected in the Leach Creek area.

5.1.18.3 Onsite Sediment. Nickel was detected in all onsite sediment samples collected during the transitional season. Concentrations ranged from 25.9 mg/kg at Location 2516 to 61.8 mg/kg at Location 2509.

Nickel was detected in 19 of 33 onsite sediment samples collected during the dry season. Concentrations ranged from undetected to 74.9 mg/kg at Location 2511. Concentrations of nickel, measured on a dry weight basis, were low in Reaches A and D compared to concentrations detected in samples collected from Reaches B and C. When normalized to percent fine-grain material, concentrations exhibited a pattern similar to those described for previous inorganic analytes.

Nickel was detected in all onsite sediment samples collected during the wet season. Concentrations ranged from 9.0 mg/kg (below CRDL) at Location 2516 to 408 mg/kg at Location 2525. Dry weight concentrations did not change significantly except in Reach B at Location 2525 where the dry weight concentration increased to 408 mg/kg from 69.3 mg/kg at Location 2526 and then declined to 46.1 mg/kg at Location 2524. When normalized to percent fine-grain material, concentrations were the most elevated in Reach A and in the northern section of Reach B. Concentrations then decreased and did not exhibit any discernible pattern.

Maximum nickel concentrations were approximately equivalent in the transitional and dry season sediment samples. The maximum wet season concentration was approximately six times greater than the transitional and dry season concentrations. The maximum nickel concentrations in sediment samples collected for all seasonal events were higher than those detected in the Leach Creek area sediment (26-60 mg/kg).

5.1.18.4 Runoff. Nickel was detected in biweekly runoff surface water samples collected from Location 2515. The biweekly surface water runoff concentrations ranged from undetected to 10.1 $\mu\text{g/L}$ (below CRDL) (see Table SW-9). The detected concentrations were below AFWQC. Runoff concentrations were within the range of runon concentrations except the three biweekly concentrations which were greater than the detected concentrations at Location 2500. The runoff concentrations were also below naturally occurring surface water concentrations and detected concentrations in the Leach Creek area.

5.1.19 Potassium

Potassium is an alkali metal. In sediment, potassium commonly is present as unaltered feldspar and mica particles or in illite or other clay materials (Hem 1989).

5.1.19.1 Background. Potassium was detected in all of the background samples collected during the dry season event. Potassium was detected in samples collected during the wet season event at three background locations: 2500, 2541, and 2542. Concentrations of potassium ranged from 2,090 (below CRDL) $\mu\text{g/L}$ to 5,840 $\mu\text{g/L}$ during the dry season and undetected to 3,380 $\mu\text{g/L}$ (below CRDL) during the wet season (see Table SW-6). EPA has not proposed WQC for potassium. Generally, potassium concentrations in the dry season background samples were higher than those detected in the wet season background samples.

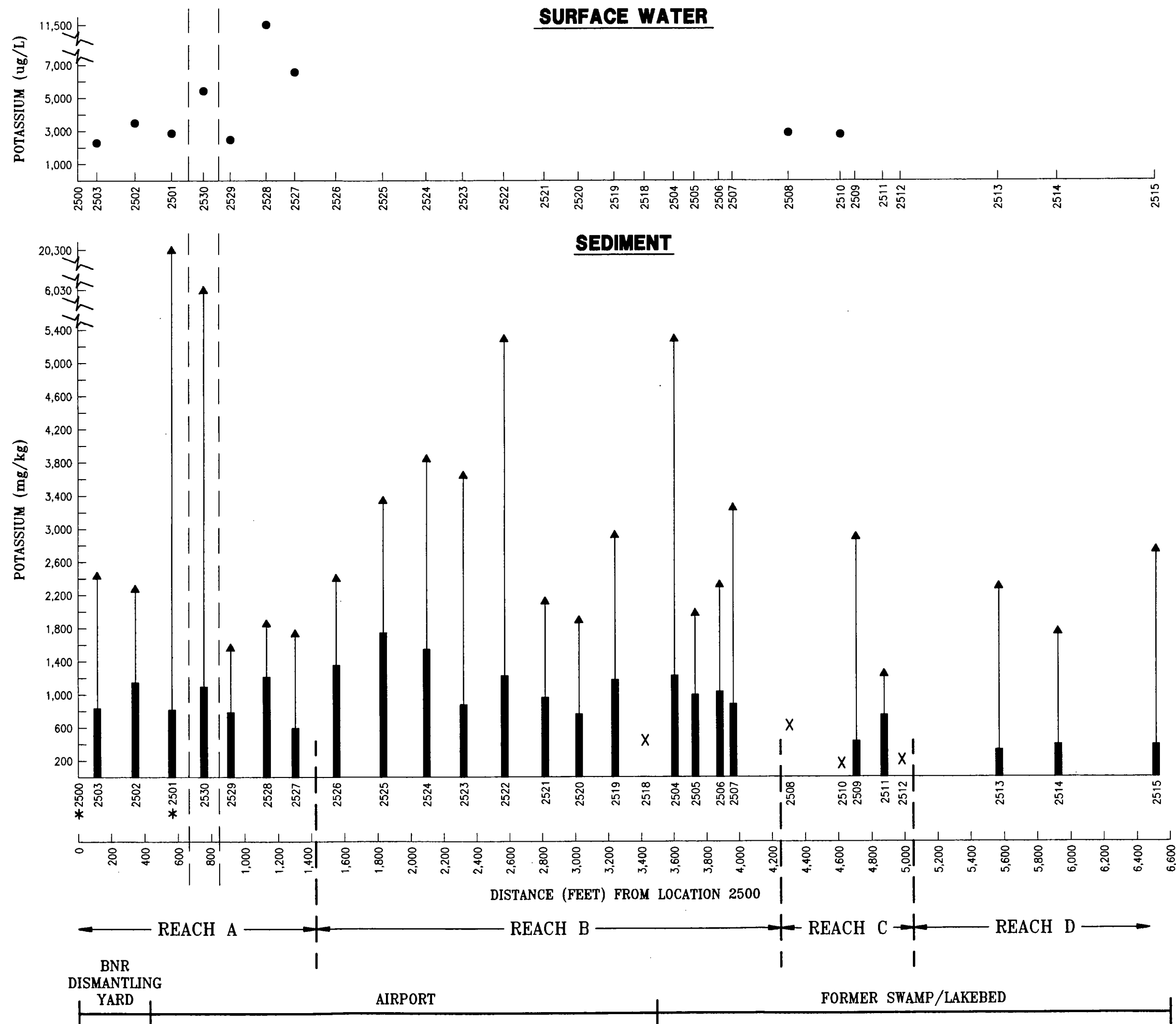
5.1.19.2 Runon. Potassium was detected in monthly and stormwater runon samples collected at both locations. Monthly surface water runon concentrations ranged from 2,450 $\mu\text{g/L}$ (below CRDL) to 14,500 $\mu\text{g/L}$ at Location 2500 and 926 $\mu\text{g/L}$ (below CRDL) to 6,320 $\mu\text{g/L}$ at Location 2501 (see Table SW-7). Stormwater runon concentrations ranged from 914 $\mu\text{g/L}$ (below CRDL) to 3,560 $\mu\text{g/L}$ (below CRDL) at Location 2500 and undetected to 5,580 $\mu\text{g/L}$ at Location 2501.

Generally, potassium concentrations in stormwater runoff samples were higher than concentrations in monthly runoff samples at Location 2501. Potassium concentrations in stormwater runoff samples were lower than concentrations in monthly runoff samples at Location 2500. The concentrations detected in monthly runoff samples collected at Location 2501 were lower than the concentrations detected in monthly runoff samples collected at Location 2500. However, the concentrations detected in stormwater runoff samples collected at Location 2501 were higher than the concentrations detected in stormwater runoff samples collected at Location 2500. Seasonal variations were not apparent with potassium concentrations. The monthly runoff concentrations exceeded the range detected in background surface water samples at Locations 2500 (four samples) and 2501 (one sample).

5.1.19.3 Onsite Surface Water. Concentrations of potassium in onsite surface water and sediment samples collected during the transitional season are presented in Appendix SW-D. Potassium was detected at concentrations below the CRDL in all samples collected during the transitional season (see Table SW-8). Concentrations ranged from 1,630 $\mu\text{g/L}$ at Location 2511 to 4,490 $\mu\text{g/L}$ at Location 2516. No concentrations exceeded the maximum runoff surface water concentration of 14,500 $\mu\text{g/L}$.

Concentrations of potassium in onsite surface water and sediment samples collected during the dry season are presented in Appendix SW-D and Figure SW-36. Potassium was detected in all onsite surface water samples collected during the dry season. Concentrations, most of which were below the CRDL, ranged from 2,280 $\mu\text{g/L}$ at Location 2503 to 11,500 $\mu\text{g/L}$ at Location 2528. The most elevated surface water concentrations were detected in samples collected from the southern section of Reach A. No concentrations exceeded the maximum runoff surface water concentration.

Concentrations of potassium in onsite surface water and sediment samples collected during the wet season are presented in Appendix SW-D and



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SOUTH TACOMA FIELD
TACOMA, WA

**POTASSIUM CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (DRY SEASON, AUGUST 1991)**

916055.24/P2SK024

FIGURE SW-36

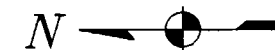
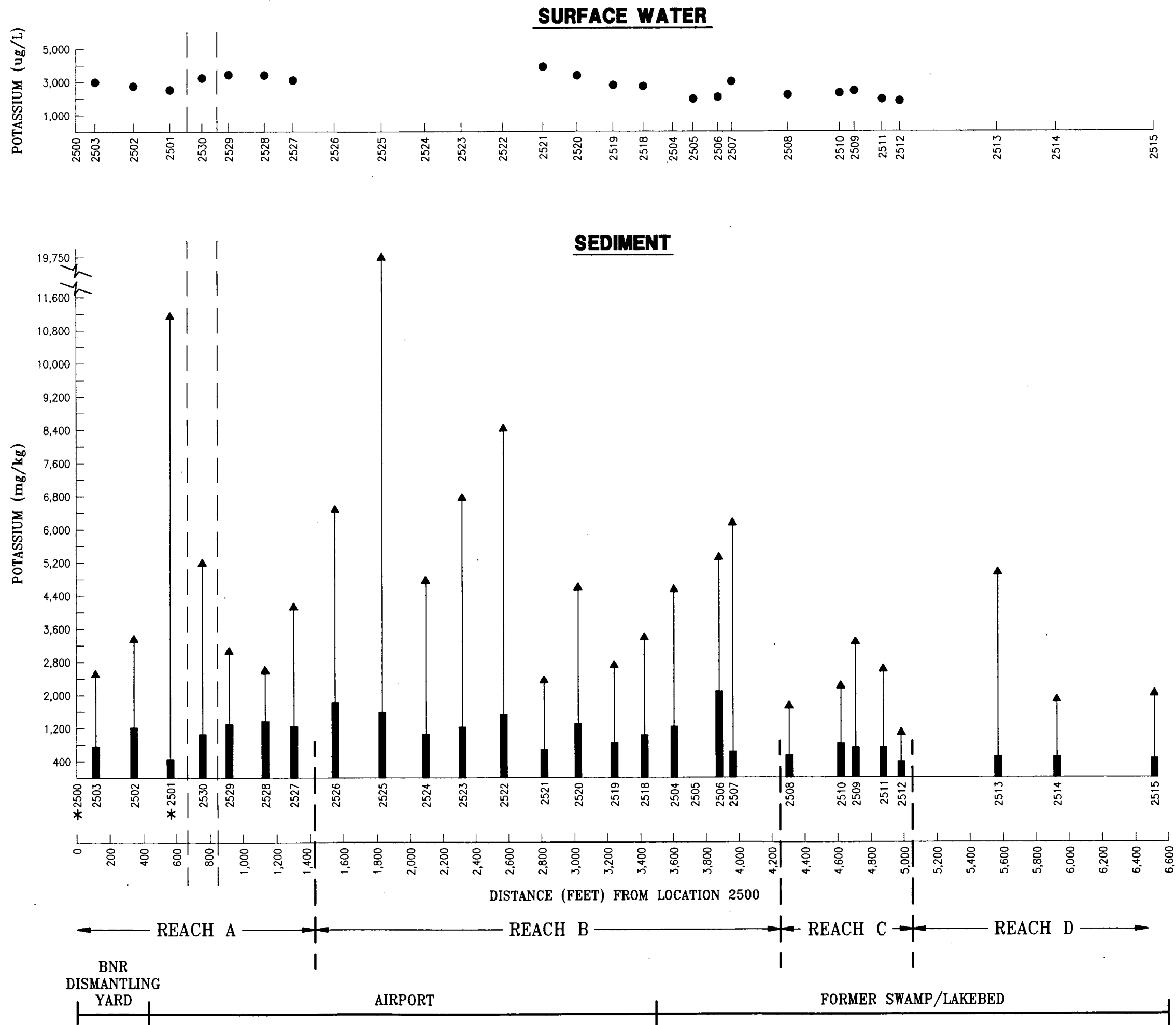
Figure SW-37. Potassium was detected in all but two surface water samples collected during the wet season. Concentrations ranged from undetected to 3,870 $\mu\text{g/L}$ at Location 2521. Surface water concentrations were fairly uniform through the channel (when surface water was present). All detected concentrations were below the CRDL. No concentrations exceeded the maximum runoff surface water concentration for potassium.

Maximum surface water potassium concentrations in the dry season were two to three times greater than the maximum concentrations in the transitional and wet season.

Potassium was detected at concentrations below the CRDL in all onsite sediment samples collected during the transitional season. Concentrations ranged from 443 mg/kg at Location 2516 to 1,210 mg/kg at Location 2506.

5.1.19.4 Onsite Sediment. Potassium was detected in most onsite sediment samples collected during the dry season. Concentrations ranged from undetected to 1,740 mg/kg at Location 2525. Based on dry weight concentrations of potassium, the most elevated potassium concentrations were detected in samples collected from Reach B. Generally, concentrations appear to decrease from Reaches A and B to Reaches C and D. When normalized to percent fine-grain material, concentrations appear to vary in a similar pattern as for inorganic analytes previously described.

Potassium was detected at concentrations below the CRDL in all onsite sediment samples (except for two) collected during the wet season. Concentrations ranged from 252 mg/kg at Location 2516 to 2,080 mg/kg at Location 2506. Dry weight concentrations did not show noteworthy changes, except at Location 2506 in Reach B. Generally, concentrations were more elevated in samples collected from Reaches A and B than from Reaches C and D. When normalized to percent fine-grain material, concentrations were the most elevated in Reaches A and B and



LEGEND

- SURFACE WATER CONCENTRATION
- DRY-WEIGHT NORMALIZATION
- ▲ FINE-GRAIN NORMALIZATION
- X 1/2 DETECTION LIMIT
- * SURFACE WATER RUNON LOCATION

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SOUTH TACOMA FIELD
TACOMA, WA

**POTASSIUM CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (WET SEASON, JANUARY 1992)**

916055.24/P2SK049

FIGURE SW-37

declined steadily through Reaches C and D. Maximum potassium concentrations were approximately similar for all onsite sediment samples.

5.1.19.5 Runoff. Potassium was detected in all biweekly surface water and stormwater runoff samples collected from Location 2515. The biweekly surface water runoff concentrations ranged from 1,130 $\mu\text{g/L}$ to 2,350 $\mu\text{g/L}$ (all below CRDL) (see Table SW-9). The stormwater runoff concentration was 1,950 $\mu\text{g/L}$ (below CRDL). Runoff concentrations were within the range of runon concentrations.

5.1.20 Selenium

Selenium is a relatively rare element with concentrations in U.S. surface water that seldom exceed 1 $\mu\text{g/L}$ (Hem 1989). Elemental selenium will co-precipitate with sediments thus reducing the levels in surface water (ATSDR 1988e).

Selenium was only detected in runon and onsite surface water samples (i.e., selenium was not detected in background or runoff surface water samples).

5.1.20.1 Runon. Selenium was detected in monthly and stormwater runon samples collected at both locations. Monthly runon concentrations ranging from undetected to 4.6 $\mu\text{g/L}$ were detected only at Location 2500 (see Table SW-7). Detected stormwater runon concentrations were 1.9 $\mu\text{g/L}$ (below CRDL) at Location 2500 and 1.8 $\mu\text{g/L}$ (below CRDL) and 8.4 $\mu\text{g/L}$ in samples collected at Location 2501. The AFWQC for selenium was not exceeded for runon samples.

Monthly runon and stormwater concentrations were similar at Location 2500. However, selenium was only detected in stormwater runon samples collected at Location 2501.

Because selenium was undetected in the background surface water samples, detected monthly and stormwater runoff concentrations were above the background concentration range. The runoff concentrations were higher than selenium concentrations detected in U.S. surface water (Hem 1989).

5.1.20.2 Onsite Surface Water. Selenium was detected in only one onsite surface water sample [3.1 $\mu\text{g/L}$ (below CRDL) at Location 2506] collected during the transitional season. Selenium was not detected onsite in surface water samples collected during the dry season and detected in only one sample [2.2 $\mu\text{g/L}$ (below CRDL) at Location 2502] collected during the wet season. The detected onsite surface water concentrations were less than those detected in runoff samples. However, the onsite detected surface water concentrations were higher than selenium concentrations detected in U.S. surface water (Hem 1989).

5.1.20.3 Onsite Sediment. Selenium was detected in two onsite sediment samples (1.0 mg/kg at Location 2506 and 0.61 mg/kg at Location 2511, both below CRDL) collected during the transitional season. Selenium was detected in six sediment samples collected during the dry season. Concentrations ranged from undetected to 3.5 mg/kg at Location 2520. Selenium was detected in 11 samples collected during the wet season. Concentrations ranged from undetected to 1.9 mg/kg at Location 2510.

5.1.21 Silver

Silver is a common minor constituent of industrial wastes. In natural waters, soluble silver is less than 10 $\mu\text{g/L}$ (Hem 1989). Silver adsorbs onto particulate matter and is typically found in association with fine-grain sediments (ATSDR 1990g).

Silver was detected in only one runoff and one onsite surface water sample (i.e., silver was not detected in background and runoff surface water samples). Silver

was detected in only one stormwater runoff sample at Location 2500 (3.5 $\mu\text{g/L}$ below CRDL) (see Table SW-7). Silver was detected at a concentration of 10.8 $\mu\text{g/L}$ (below CRDL) at Location 2516 in a sample collected during the transitional season (see Table SW-8). Both concentrations were similar to silver concentrations in natural water (Hem 1989).

Silver was detected in only one onsite sediment sample collected from all three seasonal events. Silver was detected at a concentration of 2.3 mg/kg (below CRDL) at Location 2527 in a sample collected during the dry season.

5.1.22 Sodium

Sodium is a naturally abundant alkali metal in surface water. Sodium may be present in sediment but tends to disassociate readily when water is present (Hem 1989).

5.1.22.1 Background. Sodium was detected in samples collected during the dry and wet season events at all background locations except Location 2543 (dry season event). Background concentrations of sodium ranged from undetected to 56,200 $\mu\text{g/L}$ during the dry season and from 1,600 $\mu\text{g/L}$ (below CRDL) to 12,300 $\mu\text{g/L}$ during the wet season (see Table SW-6). EPA has not proposed WQC for sodium.

In all background locations, sodium concentrations were higher in samples collected during the dry season as compared with samples collected during the wet season.

5.1.22.2 Runon. Sodium was detected in all but one runoff sample collected at Locations 2500 and 2501 (see Table SW-7). The monthly surface water runoff concentrations ranged from undetected to 453,000 $\mu\text{g/L}$ at Location 2500 and from 2,100 $\mu\text{g/L}$ to 12,600 $\mu\text{g/L}$ at Location 2501. The stormwater runoff range of

concentrations was from 10,900 $\mu\text{g/L}$ to 52,900 $\mu\text{g/L}$ at Location 2500 and from 2,540 $\mu\text{g/L}$ (below CRDL) to 9,660 $\mu\text{g/L}$ at Location 2501.

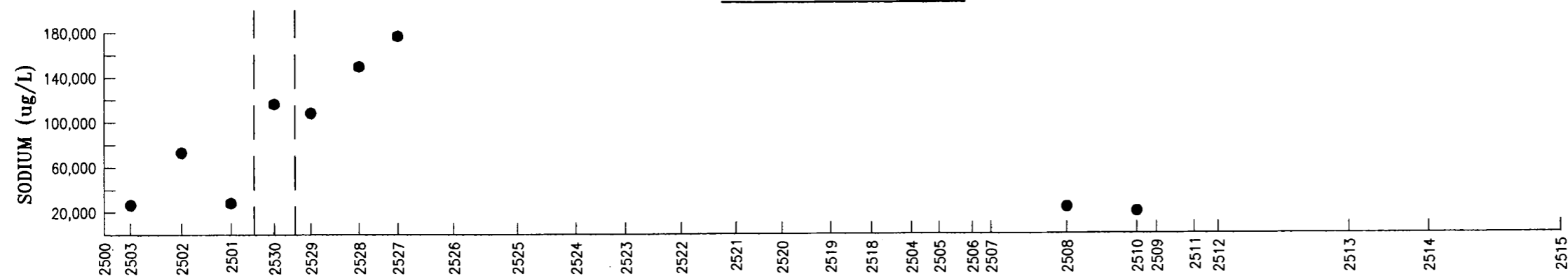
Generally, sodium concentrations in monthly runon samples were higher than concentrations in stormwater runon samples at both locations (see Appendix SW-B). The concentrations detected in monthly and stormwater runon samples collected at Location 2501 were lower than the concentrations detected in monthly and stormwater runon samples collected at Location 2500. Seasonal variations were apparent with sodium concentrations. At Location 2500, the runon concentrations were higher during the months of July to November. At Location 2501, the runon concentrations were higher during the months of October and November. The background surface water range was exceeded in three monthly event samples at Location 2500.

5.1.22.3 Onsite Surface Water. Concentrations of sodium in onsite surface water and sediment samples collected during the transitional season are presented in Appendix SW-D. Sodium was detected in all onsite surface water samples collected during the transitional season. Concentrations ranged from 15,500 $\mu\text{g/L}$ at Location 2511 to 77,100 $\mu\text{g/L}$ at Location 2509 (see Table SW-8). No concentrations exceeded the maximum runon surface water concentration of 453,000 $\mu\text{g/L}$.

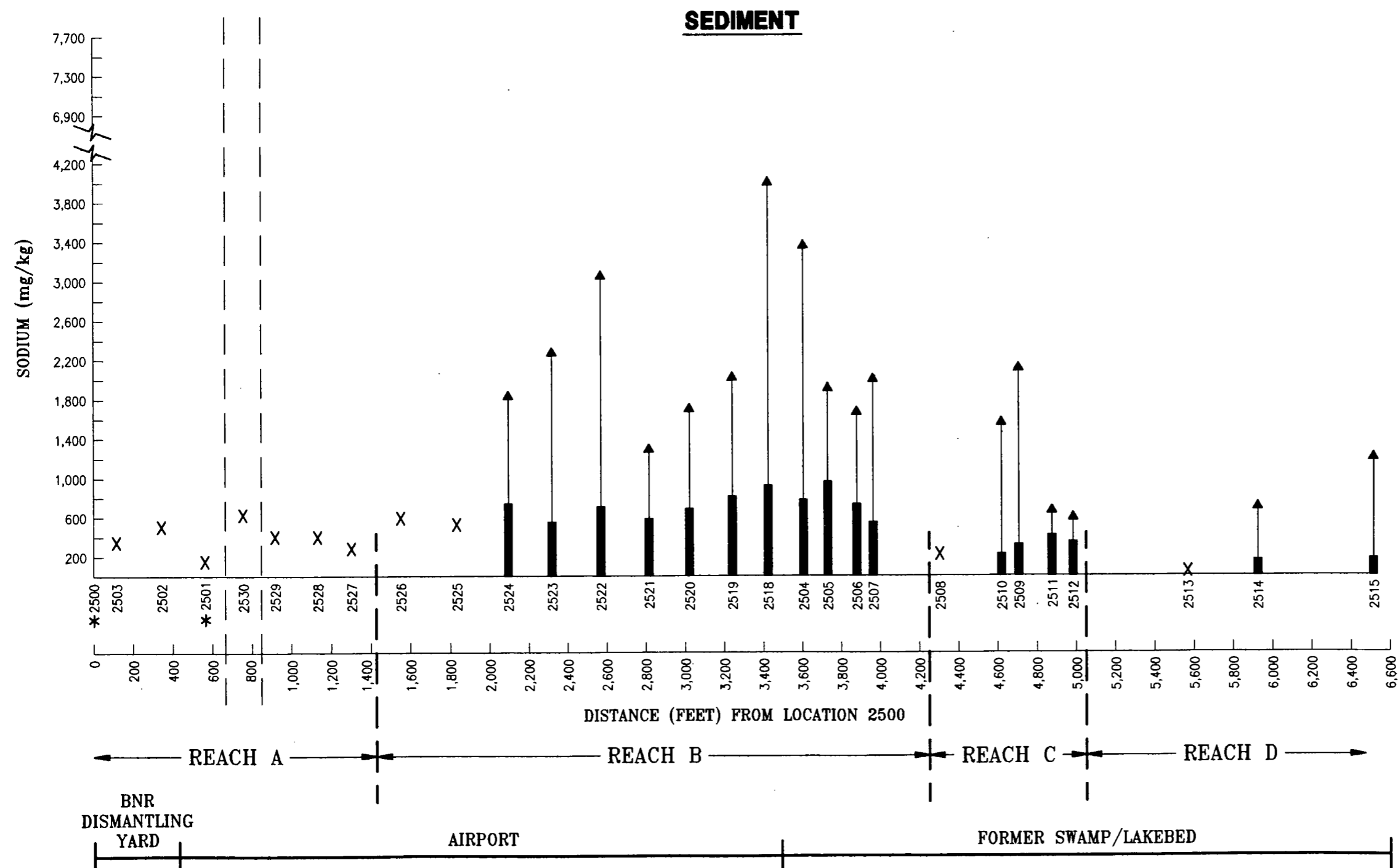
Concentrations of sodium in onsite surface water and sediment samples collected during the dry season are presented in Appendix SW-D and Figure SW-38. Sodium was detected in all onsite surface water samples collected during the dry season. Concentrations ranged from 19,200 $\mu\text{g/L}$ at Location 2510 to 176,000 $\mu\text{g/L}$ at Location 2527. Surface water concentrations trended upward from north to south in Reach A. No concentrations exceeded the maximum runon surface water concentration.

Concentrations of sodium in surface water and sediment samples collected during the wet season are presented in Appendix SW-D and Figure SW-39. Sodium was

SURFACE WATER



SEDIMENT



LEGEND

- SURFACE WATER CONCENTRATION
- DRY-WEIGHT NORMALIZATION
- ▲ FINE-GRAIN NORMALIZATION
- X 1/2 DETECTION LIMIT
- * SURFACE WATER RUNON LOCATION

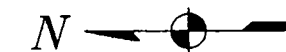
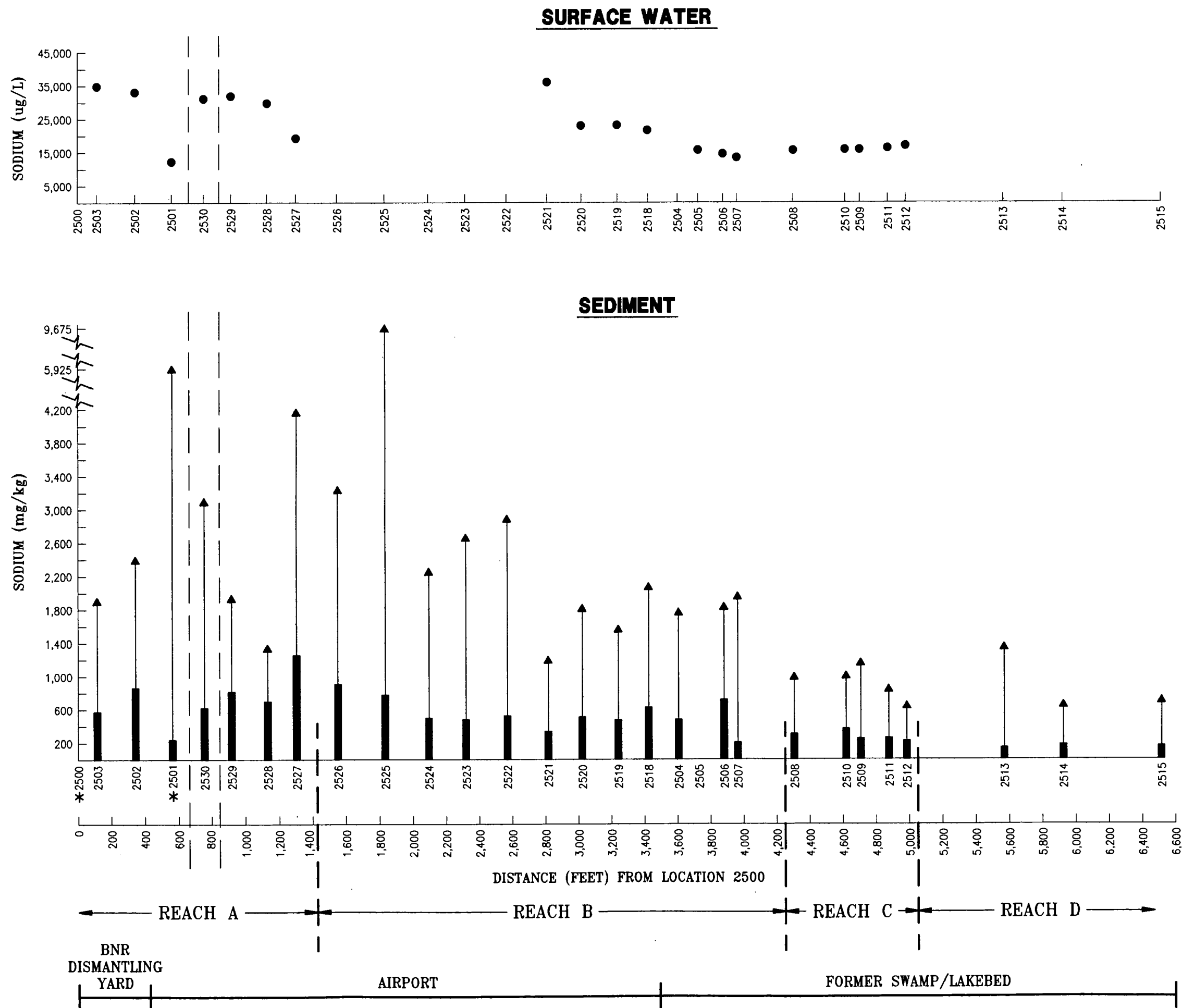
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SOUTH TACOMA FIELD
TACOMA, WA

**SODIUM CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (DRY SEASON, AUGUST 1991)**

916055.24/P2SK025

FIGURE SW-38



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SOUTH TACOMA FIELD
TACOMA, WA

**SODIUM CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (WET SEASON, JANUARY 1992)**

916055.24/P2SK050

FIGURE SW-39

detected in all surface water samples collected during the wet season.

Concentrations ranged from 1,880 $\mu\text{g/L}$ (below CRDL) at Location 2516 to 35,900 $\mu\text{g/L}$ at Location 2521. Sodium concentrations were generally higher in Reach A and the north and central sections of Reach B. Concentrations declined from these elevated levels and remained fairly constant through the remainder of Reach B and all of Reach C. No concentrations exceeded the maximum runoff surface water concentration.

Maximum onsite surface water sodium concentrations detected in the dry season surface water samples were approximately three to five times greater than the maximum concentrations detected in the transitional and wet season samples.

5.1.22.4 Onsite Sediment. Sodium was detected at concentrations below the CRDL in four of five onsite sediment samples collected during the transitional season. Concentrations ranged from undetected to 1,780 mg/kg at Location 2506.

Sodium was detected (all below CRDL) in 22 of 33 onsite sediment samples collected during the dry season. Concentrations ranged from undetected to 962 mg/kg at Location 2505. Concentrations are highest in the samples collected in the southern section of Reach B and decline in samples collected from Reaches C and D. When normalized to percent fine-grain material, concentrations were more elevated throughout Reach B, and then decreased in Reaches C and D.

Sodium was detected at concentrations below the CRDL in all onsite sediment samples collected during the wet season. Concentrations ranged from 71.8 mg/kg at Location 2516 to 1,250 mg/kg at Location 2527. Dry weight concentrations increased from Reach A to a peak at Location 2527 and then decreased throughout the remainder of the surface water channel. When normalized to percent fine-grain material, concentrations were highest in Reach A and the northern section of Reach B before decreasing steadily through the remainder of the surface water channel.

Maximum onsite sediment sodium concentrations were approximately equivalent among sampling seasons.

5.1.22.5 Runoff. Sodium was detected in all biweekly surface water and stormwater runoff samples collected from Location 2515. The biweekly surface water runoff concentrations ranged from 2,090 $\mu\text{g/L}$ (below CRDL) to 14,700 $\mu\text{g/L}$ (see Table SW-9). The stormwater runoff concentration was 16,200 $\mu\text{g/L}$, which was greater than the biweekly surface water runoff concentrations. Runoff concentrations were within the range of runoff concentrations except for two biweekly runoff concentrations which were greater than detected runoff concentrations at Location 2501.

5.1.23 Thallium

Thallium is a nonvolatile metal that is naturally occurring in ambient waters in trace amounts. Concentrations of 1-14 $\mu\text{g/L}$ have been detected in 10 percent of urban stormwater runoff samples collected. Elevated concentrations have been measured in industrial and commercial areas. Up to 5 mg/kg have been reported in stream sediment near metal industry runoff areas (ATSDR 1990h).

Thallium was undetected in all surface water and sediment samples collected during this investigation, except for one monthly runoff surface water sample collected at Location 2500 (19.5 $\mu\text{g/L}$) (see Table SW-7).

5.1.24 Vanadium

Vanadium is a transitional metal that is naturally present in plants and soils and can be released by combustion, deposition and erosion and leaching of soils. Concentrations of vanadium in surface waters are typically less than 10 $\mu\text{g/L}$.

(Hem 1989; ATSDR 1990i). Anthropogenic releases to sediment are far smaller than natural sources (ATSDR 1990).

5.1.24.1 Background. Vanadium was not detected in any of the background samples collected during the dry season event. Vanadium was detected below the CRDL in samples collected during the wet season event at all background locations except Location 2500, where it was undetected. Wet season event background concentrations ranged from undetected to 9.1 $\mu\text{g/L}$ (below CRDL) (see Table SW-6). EPA has not proposed WQC for vanadium.

5.1.24.2 Runon. Vanadium was detected in monthly runon samples at concentrations ranging from undetected to 7.2 $\mu\text{g/L}$ at Location 2500 and from undetected to 48.1 $\mu\text{g/L}$ at Location 2501 (all below CRDL) (see Table SW-7). Vanadium was detected in stormwater runon samples at concentrations ranging from undetected to 9.4 $\mu\text{g/L}$ at Location 2500 (all below CRDL) and from undetected to 66.9 $\mu\text{g/L}$ at Location 2501.

Generally, vanadium concentrations in stormwater runon samples were higher than concentrations in monthly runon samples at both locations (see Appendix SW-B). Concentrations detected in monthly and stormwater runon samples collected at Location 2501 were higher than the concentrations detected at Location 2500. Seasonal variations were not apparent at Location 2500. However, vanadium concentrations were increased during the months of June to December at Location 2501.

Vanadium concentrations detected in runon samples collected at Location 2500 were within the background surface water concentration range. However, concentrations detected in runon samples collected at Location 2501 were greater than the background surface water concentration range. Vanadium concentrations detected at Location 2501 also exceeded typical concentrations detected surface waters (10 $\mu\text{g/L}$).

5.1.24.3 Onsite Surface Water. Vanadium was not detected in onsite surface water samples collected during the transitional season. Concentrations of vanadium in onsite surface water and sediment samples collected during the dry season are presented in Appendix SW-D and Figure SW-40. Vanadium was detected in five of the nine surface water samples collected during the dry season. Concentrations ranged from undetected to 146 $\mu\text{g/L}$ at Location 2528 (see Table SW-8). Of the five detected concentrations, four were below the CRDL. The most elevated surface water concentrations were detected in samples collected from the southern section of Reach A. The concentration associated with the sample collected from Location 2528 exceeded the maximum runon surface water concentration of 66.9 $\mu\text{g/L}$.

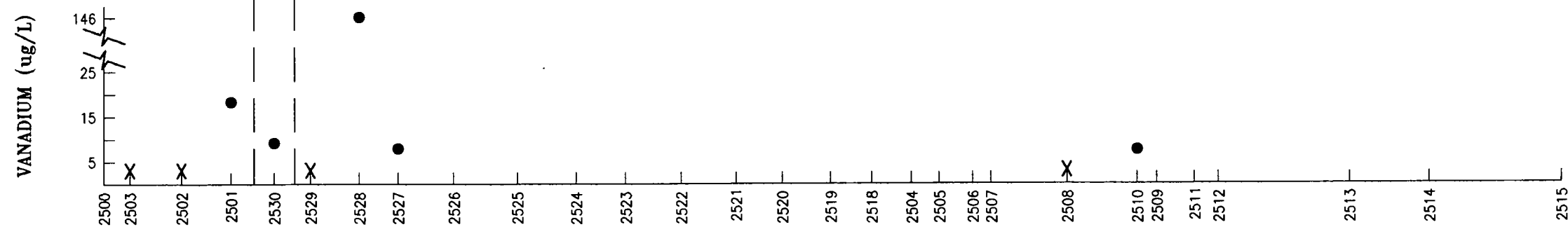
Concentrations of vanadium in onsite surface water and sediment samples collected during the wet season are presented in Appendix SW-D and Figure SW-41. Vanadium was detected in 11 of 24 surface water samples collected during the wet season. Concentrations ranged from undetected to 14.8 $\mu\text{g/L}$ at Location 2527 (see Table SW-8). All detected concentrations were below the CRDL. Vanadium concentrations in wet season samples increased from north to south in Reach A. No concentrations exceeded the maximum runon surface water concentration.

The maximum surface water vanadium concentration in the dry season was approximately one order of magnitude greater than in the wet season. The detected onsite surface water concentrations were higher than typical surface water concentrations (10 $\mu\text{g/L}$) (Hem 1989) in two samples collected during the dry and wet seasons.

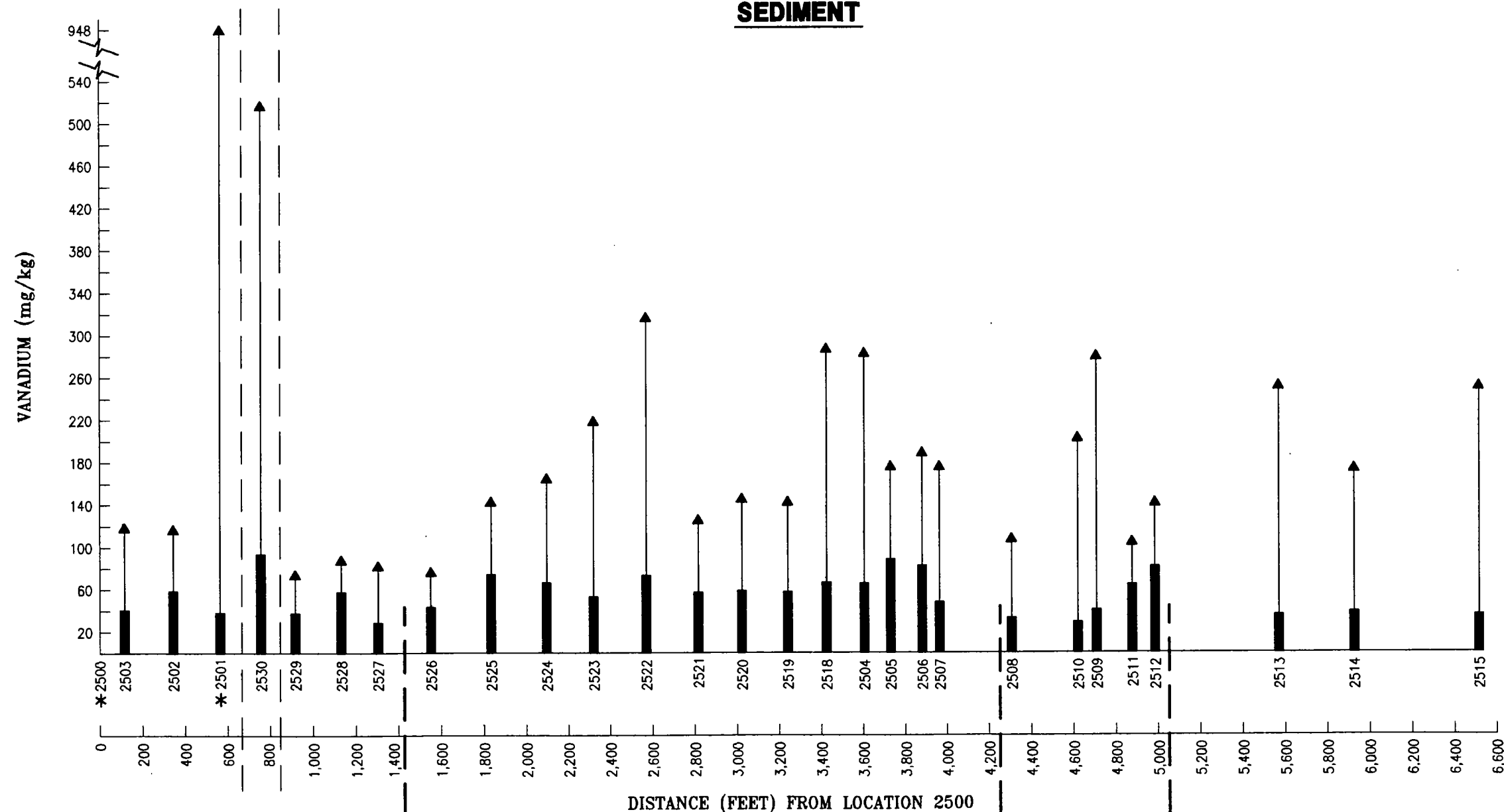
Vanadium was detected in all onsite sediment samples collected during the transitional season. Concentrations ranged from 22.6 mg/kg at Location 2516 to 74.2 mg/kg at Location 2506.

5.1.24.4 Onsite Sediment. Vanadium was detected in all onsite sediment samples collected during the dry season. Concentrations ranged from 22.8 mg/kg at

SURFACE WATER



SEDIMENT



LEGEND

- SURFACE WATER CONCENTRATION
- DRY-WEIGHT NORMALIZATION
- ▲ FINE-GRAIN NORMALIZATION
- X 1/2 DETECTION LIMIT
- * SURFACE WATER RUNON LOCATION

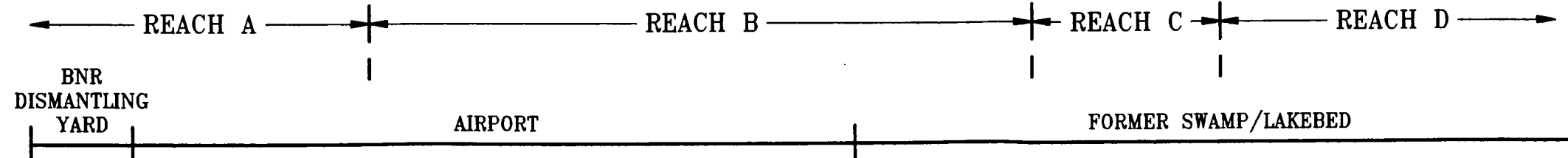
Kennedy/Jenks Consultants

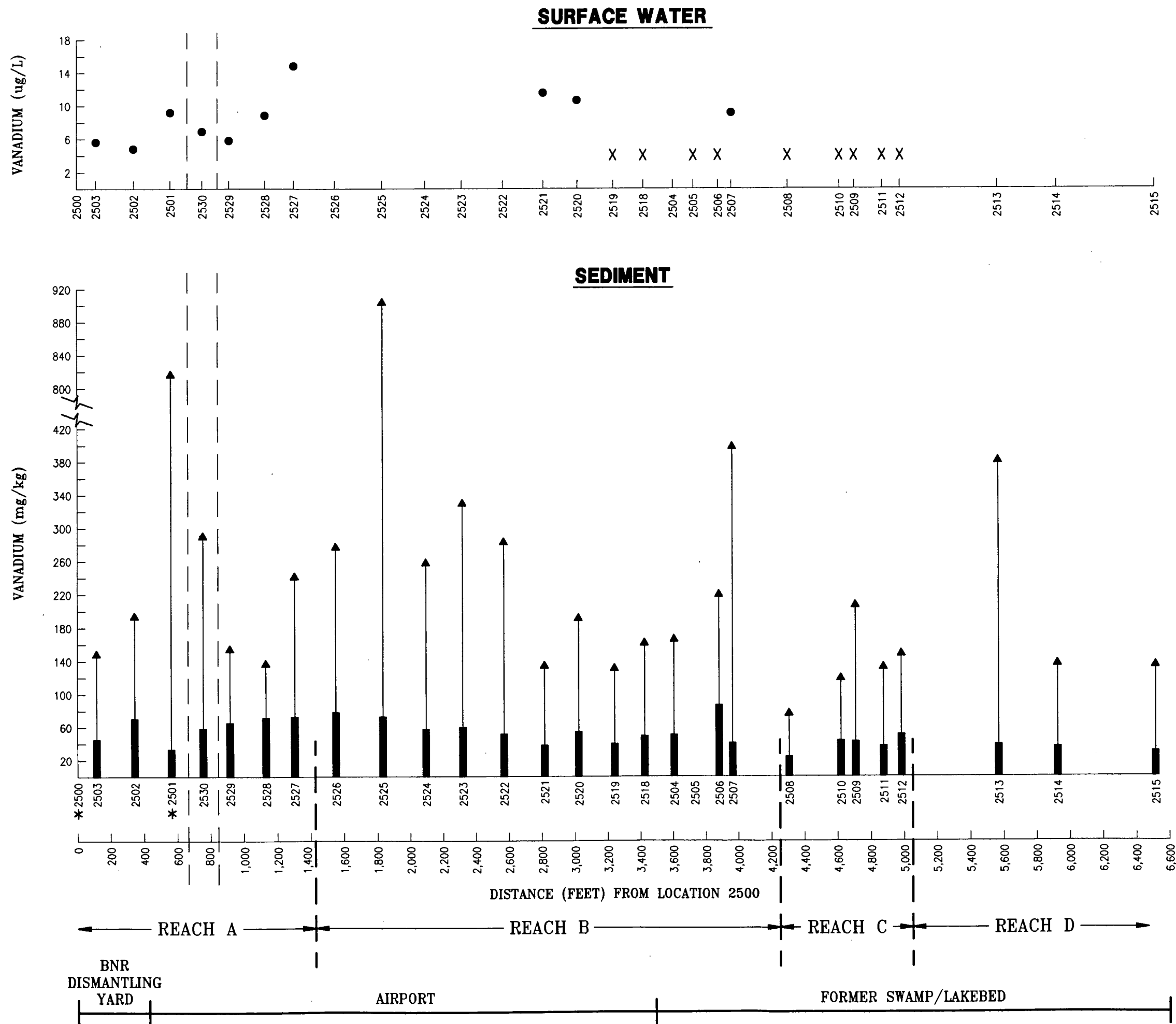
SOUTH TACOMA FIELD
TACOMA, WA

**VANADIUM CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (DRY SEASON, AUGUST 1991)**

916055.24/P2SK026

FIGURE SW-40





LEGEND

- SURFACE WATER CONCENTRATION
- DRY-WEIGHT NORMALIZATION
- ▲ FINE-GRAIN NORMALIZATION
- X 1/2 DETECTION LIMIT
- * SURFACE WATER RUNON LOCATION

Kennedy/Jenks Consultants

SOUTH TACOMA FIELD
TACOMA, WA

**VANADIUM CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (WET SEASON, JANUARY 1992)**

916055.24/P2SK051

FIGURE SW-41

Location 2516 to 93.0 mg/kg at Location 2530. Dry weight concentrations appeared to remain fairly constant throughout the surface water channel. When normalized to percent fine-grain material, concentrations were highest in Reach A and have a similar trend as the previously discussed inorganic analytes.

Vanadium was detected in all onsite sediment samples collected during the wet season. Concentrations ranged from 9.3 mg/kg (below CRDL) at Location 2516 to 86.0 mg/kg at Location 2506. Generally, dry weight concentrations were the most elevated in Reach A and the northern section of Reach B, and decreased slightly in Reaches C and D. When normalized to percent fine-grain material, the most elevated concentrations were in Reaches A and B; concentrations then decreased, although elevated normalized concentrations were exhibited at locations in the southern section of Reach B and in Reach D.

Maximum vanadium concentrations were approximately equivalent for all onsite sediment samples collected during all seasonal sampling events.

5.1.24.5 Runoff. Vanadium was not detected in the stormwater runoff sample. Vanadium was detected in one biweekly surface water runoff sample at a concentration of 4.2 $\mu\text{g/L}$ (below CRDL). The runoff concentration was within the range of runoff concentrations and below concentrations typically detected in surface water (less than 10 $\mu\text{g/L}$).

5.1.25 Zinc

Zinc occurs naturally in all surface waters at an average concentration of 10 $\mu\text{g/L}$, however the concentrations detected in surface water are greatly enhanced by modern industrialized civilization (Hem 1989). Urban runoff provides a smaller but more concentrated source of zinc to surface water in comparison to erosion of natural zinc-laden soil. Concentrations of zinc detected in surface water samples ranged from 2 $\mu\text{g/L}$ to 1,200 $\mu\text{g/L}$. The National Urban Runoff Program reported a

range of 10 $\mu\text{g/L}$ -2,400 $\mu\text{g/L}$ (ATSDR 1988h). In the vicinity of STF, concentrations of zinc were detected below 28 $\mu\text{g/L}$ in the Leach Creek area in January 1983. A zinc concentration of 9,810 $\mu\text{g/L}$ was detected in a sample collected from a heavy flow of a leachate/runoff seep from a catch basin in the Leach Creek area in January 1983 (Lum and Turney 1985).

Zinc can occur in both suspended and dissolved forms in surface water. The dominant fate of zinc is to partition to sediment or suspended solids in surface water. Thus, zinc tends to concentrate in sediment (ATSDR 1988h). In the vicinity of STF, the concentrations of zinc detected in sediment in the Leach Creek area ranged from 129 mg/kg to 658 mg/kg (Lum and Turney 1985).

5.1.25.1 Background. Zinc was detected in background samples collected during the dry season event at Locations 2500 (43.6 $\mu\text{g/L}$), 2541 (75.7 $\mu\text{g/L}$), and 2543 (35.1 $\mu\text{g/L}$). The 1-hour average WQC for Location 2543 (28.2 $\mu\text{g/L}$) was exceeded in the sample collected during the dry season.

Zinc was detected in all of the background samples collected during the wet season event except at Location 2540. Wet season background concentrations of zinc ranged from undetected to 96.4 $\mu\text{g/L}$. The 1-hour average WQC for Location 2541 (77.68 $\mu\text{g/L}$) was exceeded in the sample collected during that season. A seasonal variation of detected zinc concentrations was not apparent.

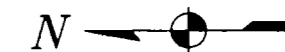
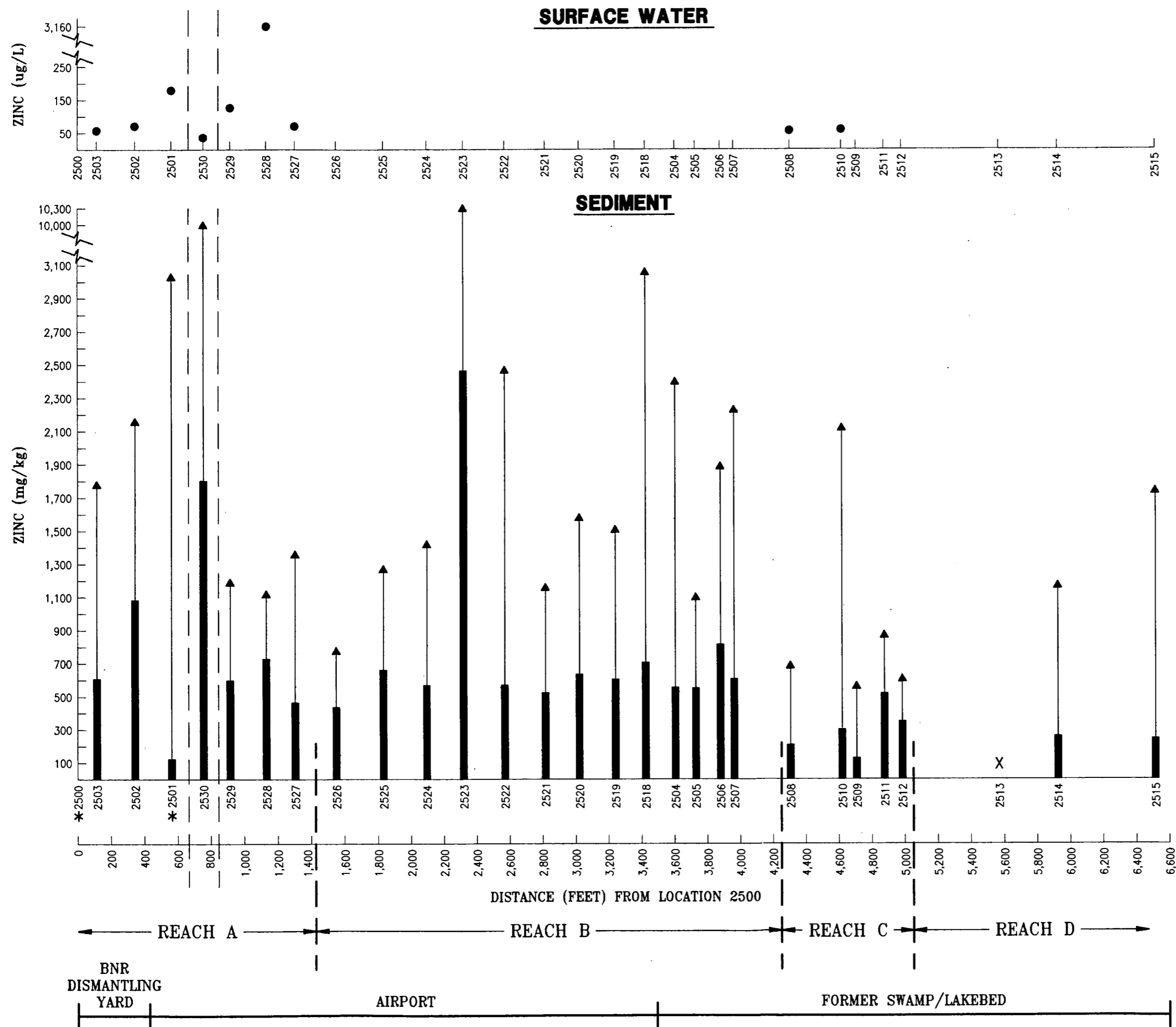
5.1.25.2 Runon. Zinc was detected in surface water runon samples collected at both locations. Monthly runon samples concentrations ranged from undetected to 271 $\mu\text{g/L}$ at Location 2500 and from 19.2 $\mu\text{g/L}$ (below CRDL) to 171 $\mu\text{g/L}$ at Location 2501. Stormwater runon concentrations ranged from 82 $\mu\text{g/L}$ to 325 $\mu\text{g/L}$ at Location 2500 and from 57.5 $\mu\text{g/L}$ to 241 $\mu\text{g/L}$ at Location 2501. The 1-hour average WQC was exceeded at Locations 2500 (five samples) and 2501 (two samples) for the monthly runon concentrations detected. The 1-hour average WQC was exceeded at Locations 2500 and 2501 for all stormwater runon concentrations.

Generally, zinc concentrations in stormwater runoff samples were higher than concentrations in monthly runoff samples at both locations (see Appendix SW-B). Concentrations detected in monthly runoff samples collected at Location 2500 were higher than those detected in monthly runoff samples collected at Location 2501. Seasonal variations were apparent with monthly zinc concentrations, increasing from June 1991 to January 1992 at both locations.

Generally, the runoff zinc concentrations were greater than the background surface water range except for the monthly runoff samples collected at Location 2501. In addition, the runoff zinc concentrations were greater than naturally occurring concentrations of $10 \mu\text{g/L}$ and the concentrations detected in the USGS study. One concentration of $9,810 \mu\text{g/L}$ detected in the surface water in the Leach Creek area was above the STF runoff concentrations detected. This high concentration has been attributed to urban contributions.

5.1.25.3 Onsite Surface Water. Zinc was not detected in onsite surface water samples collected during the transitional season. Concentrations of zinc in onsite surface water and sediment samples collected during the dry season are presented in Appendix SW-D and Figure SW-42. Zinc was detected in all surface water samples collected during the dry season. Concentrations ranged from $35.7 \mu\text{g/L}$ at Location 2530 to $3,160 \mu\text{g/L}$ at Location 2528. Onsite surface water concentrations were fairly uniform except for the concentration associated with the sample collected from Location 2528 in the southern section of Reach A. One concentration (sample collected from Location 2528) exceeded the maximum runoff surface water concentration of $325 \mu\text{g/L}$. The AFWQC for zinc ($88.25 \mu\text{g/L}$) was exceeded at three locations.

Concentrations of zinc in onsite surface water and sediment samples collected during the wet season (January 1992) from the surface water drainage channel are presented in Appendix SW-D and Figure SW-43. Zinc was detected in all but two surface water samples collected during the wet season. Concentrations ranged from undetected to $215 \mu\text{g/L}$ at Location 2527. Surface water concentrations were



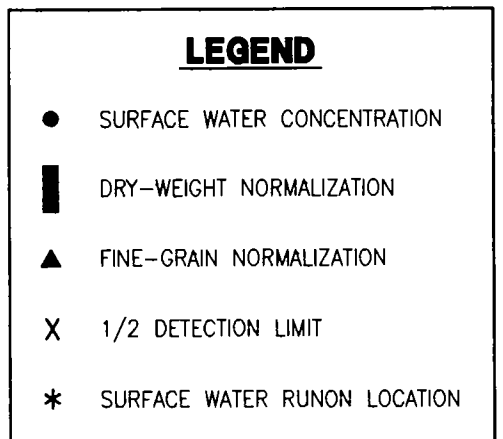
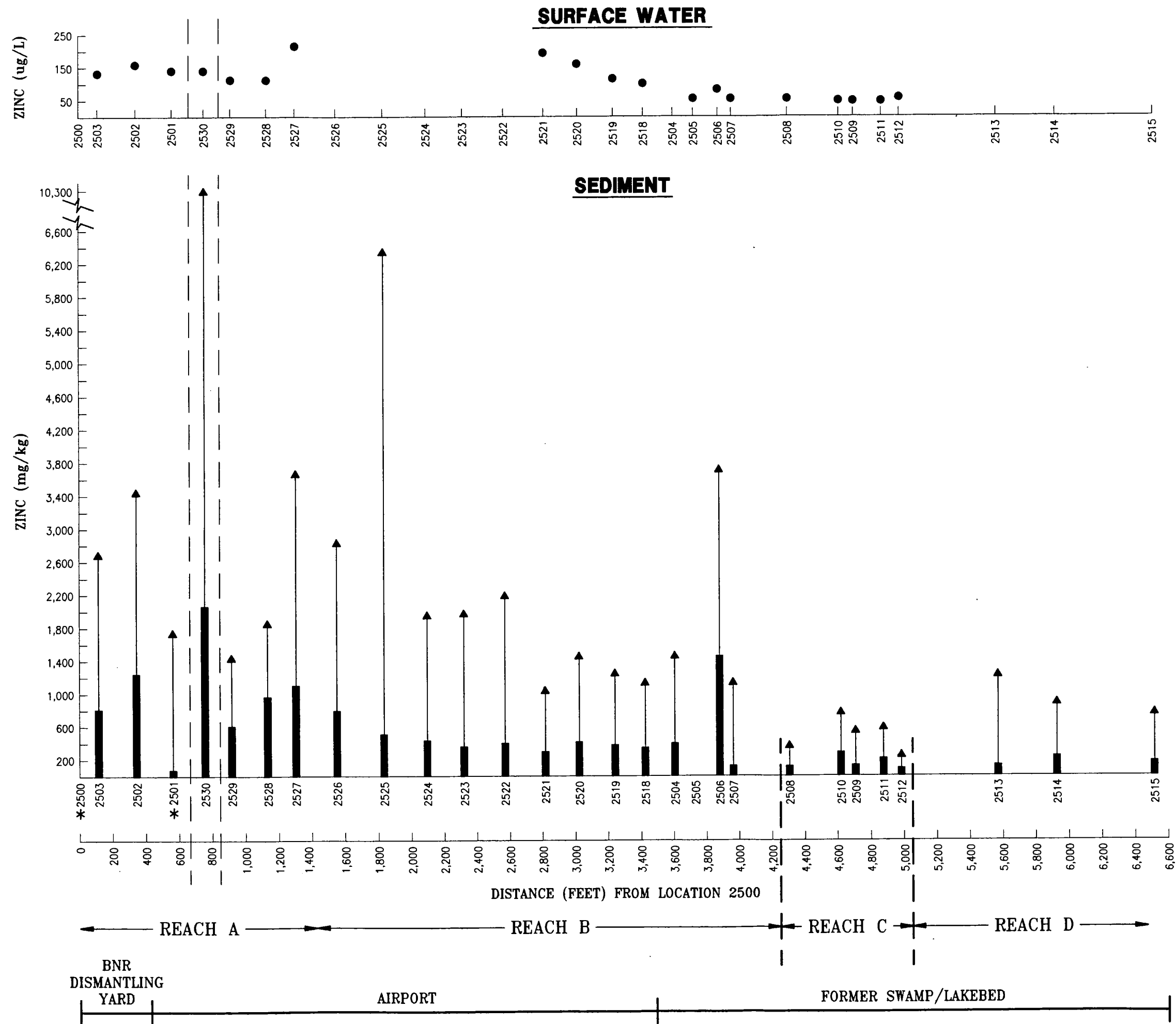
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SOUTH TACOMA FIELD
TACOMA, WA

**ZINC CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (DRY SEASON, AUGUST 1991)**

916055.24/P2SK027

FIGURE SW-42



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SOUTH TACOMA FIELD
TACOMA, WA

**ZINC CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (WET SEASON, JANUARY 1992)**

916055.24/P2SK052

FIGURE SW-43

fairly uniform in Reach A; the most elevated concentration was detected in the sample collected from Location 2527. In Reach B, concentrations were detected in the southern section and decreased steadily before leveling off at 2505 and remained fairly constant through the southern end of Reach C. No detected concentrations exceeded the maximum runoff surface water concentration. The AFWQC for zinc ($49.2 \mu\text{g/L}$) was exceeded in most locations.

The maximum onsite surface water zinc concentration in the dry season was more than one order of magnitude greater than in the wet season. Generally, the onsite surface water concentrations were above natural water concentrations ($10 \mu\text{g/L}$) and detected concentrations in the Leach Creek area ($28 \mu\text{g/L}$). However, the onsite surface zinc concentration were generally within the range of zinc concentrations for the National Urban Runoff Program as reported in ATSDR (1988h).

5.1.25.4 Onsite Sediment. Zinc was detected at estimated concentrations in all onsite sediment samples collected during the transitional season. Concentrations ranged from 36.6 mg/kg at Location 2516 to 842 mg/kg at Location 2506.

Zinc was detected in all but one onsite sediment sample collected during the dry season. Concentrations ranged from undetected to 2,460 mg/kg at Location 2523. Dry weight concentrations of zinc were elevated in Reach A and then decreased steadily through the remainder of the surface water channel except for at Location 2506 in the southern section of Reach B where an elevated concentration of 1,450 mg/kg was reported. When normalized to percent fine-grain material, concentrations were elevated in the northern section of Reach A. Elevated concentrations were also noted in several locations in Reach B. Concentrations decreased in the southern section of Reach B and Reach C before increasing in Reach D.

Zinc was detected in all onsite sediment samples collected during the wet season. Concentrations ranged from 18.7 mg/kg at Location 2516 to 2,060 mg/kg at

Location 2530. Dry weight concentrations of zinc were the most elevated in Reach A and then decreased through Reach B before leveling off in Reaches C and D. When normalized to percent fine-grain material, concentrations were the most elevated in Reach A and the northern most portion of Reach B. Normalized concentrations decreased swiftly after Location 2525, and generally decreased through the remainder of the channel.

Maximum onsite zinc concentrations were approximately two to three times greater in the dry and wet season sediment samples compared to the transitional season sediment samples. The range of onsite sediment zinc concentrations (transitional, dry, and wet seasons) exceeded the range of concentrations detected in the Leach Creek area sediment.

5.1.25.5 Runoff. Zinc was detected in all biweekly surface water and stormwater runoff samples collected from Location 2515. The biweekly surface water runoff concentrations ranged from 22.4 $\mu\text{g/L}$ to 40.4 $\mu\text{g/L}$. The stormwater runoff concentration was 48.0 $\mu\text{g/L}$, which was greater than all the biweekly surface water runoff concentrations. Concentrations of three biweekly surface water and the stormwater runoff samples exceeded the AFWQC. Runoff concentrations were within the range of runoff concentrations. The runoff zinc concentrations were greater than naturally occurring concentrations (average 10 $\mu\text{g/L}$), within national range of concentrations, and greater than the concentrations detected in the Leach Creek area (except for one location).

5.1.26 Summary of Inorganic Results

Eleven inorganic compounds were detected consistently in samples collected from the background locations. Inorganics detected at the background locations were aluminum, barium, calcium, copper, iron, lead, magnesium, manganese, potassium, sodium, and zinc. Aluminum, copper, and zinc concentrations exceeded AFWQC at least once in background samples.

Seasonal variations were apparent for some of the inorganics. Aluminum, copper, lead, magnesium, manganese, potassium, and sodium generally were detected at higher concentrations in samples collected during the dry season. Arsenic and vanadium generally were detected at higher concentrations in samples collected during the wet season.

Aluminum, arsenic, barium, calcium, copper, total chromium, iron, magnesium, manganese, potassium, sodium, vanadium, and zinc were commonly detected in both the monthly surface water and stormwater runon. Generally, these inorganics were detected at higher concentrations in the stormwater runon samples than those detected in the monthly surface water runon samples. Boron, calcium, and sodium concentrations at both runon locations and magnesium and potassium concentrations at Location 2500 were higher in the monthly surface water runon samples than the stormwater runon samples.

Aluminum, arsenic, barium, chromium, iron, lead, manganese, nickel, and vanadium were detected more frequently and at higher concentrations at Location 2501 in both the monthly and stormwater runon samples. In addition, arsenic and cobalt were detected at higher concentrations in monthly runon samples collected at Location 2501. Calcium, copper, magnesium, and potassium were detected at higher concentrations in stormwater runon samples collected at Location 2501.

Sodium and zinc were detected at higher concentrations in both the monthly and stormwater runon samples collected at Location 2500.

Aluminum, cadmium (one monthly runon sample collected at Location 2501), copper, lead, and zinc concentrations exceeded AFWQC.

Higher concentrations of several inorganics were detected in runon samples collected during the months of June to October. These inorganics included aluminum, arsenic, barium, copper, iron, lead, magnesium, manganese, sodium, and vanadium (at Location 2501 only).

Several inorganic concentrations detected in the runoff samples exceeded the concentrations detected in background surface water samples. Based on review of regional and national levels of natural concentrations, some inorganics were detected above natural levels. Aluminum, arsenic, barium, boron, cadmium, chromium (at Location 2500), mercury, potassium, and sodium exceeded background concentrations, but were within reported local and national concentrations. Inorganics detected above documented regional and national concentrations are attributed anthropogenic sources to runoff surface water. Chromium (at Location 2501), copper, lead, nickel (stormwater at Location 2501), vanadium (at Location 2501), and zinc are contributing to the quality of the onsite surface water.

Generally, inorganics were detected in most onsite surface water samples collected during all three seasonal sampling events, but the most elevated levels were associated with samples collected during the dry season.

Onsite surface water concentrations exceeded ambient WQC for several inorganics including aluminum, cadmium, copper, lead, silver, and zinc. Concentrations exceeded ambient WQC most frequently (i.e., at the greatest number of sampling locations) in the wet season. The transitional season samples showed the least number of exceedances, but that was probably due to the low number of samples collected during that event.

Maximum concentrations associated with onsite samples collected during the dry season exceeded the maximum runoff concentrations (samples collected from Locations 2500 and 2501) for many inorganics. During the transitional and wet seasons, maximum onsite surface water concentrations exceeded the maximum background concentrations for only a few inorganics (i.e., cadmium, lead, manganese, and silver).

Onsite surface water maximum concentrations for inorganics generally exceeded background surface water maximum concentrations by less than 1 order of

magnitude during the dry season. In the wet season, onsite concentrations were similar, although somewhat greater, than background concentrations.

The most elevated concentrations of inorganics in samples collected during the dry season were from Reach A. Detected concentrations were also evident in samples collected from Reach C; these concentrations were generally lower relative to concentrations associated with samples from Reach A. During the wet season, surface water concentrations for inorganics generally were relatively constant or increased through most of Reach A and peaked at Location 2527. In Reach B, concentrations were generally highest at Location 2521 (the first location where surface water samples were collected in Reach B) and then decreased or remained fairly uniform into Reach C. For some inorganics (i.e., arsenic, barium, and calcium), concentrations increased slightly at the southern end of Reach C.

Generally, inorganics were detected in onsite sediment samples collected throughout the surface water channel. Inorganic concentrations associated with sediment samples collected during the dry and wet seasons were equivalent. Inorganic concentrations in onsite sediment samples collected during these seasons generally were more elevated in Reaches A and B and diminished in Reaches C and D.

Aluminum, copper, and zinc concentrations exceeded the AFWQC in all runoff samples collected at Location 2515. The biweekly runoff concentrations of aluminum, barium, and chromium exceeded the range of concentrations detected in the runoff monthly surface water sampled at Location 2500 only. Nickel concentration was detected in stormwater above the range of runoff stormwater concentrations at Location 2500. Sodium concentrations detected in biweekly and stormwater runoff samples exceeded the range of concentrations detected at runoff Location 2501 (monthly and storm). However, the inorganic concentrations detected in the runoff samples collected at Location 2515 were generally within reported concentrations occurring in U.S. surface water.

5.2 ORGANICS

Analytical results for organic chemicals (i.e., PAHs, VOCs, semivolatiles, and pesticides/PCBs) detected in surface water and sediment samples collected during this investigation are presented in this section. Comparisons of organic concentrations detected in background runoff, onsite, and runoff surface water samples to WQC for these organic analytes are presented in Tables SW-10 through SW-13. Analytical results of all organic analytes are presented in Section 7.0 of the Data Appendix.

5.2.1 PAHs

PAH analyses were performed on surface water and sediment samples collected during this investigation. Laboratory PAH results were obtained using EPA Methods 8310 and 8270. Only PAH analyses were performed on surface water runoff samples collected during monthly and storm sampling events. PAH results were obtained using EPA Method 8310 only. Because EPA Method 8310 is capable of achieving lower detection limits for PAHs, only those analyses were discussed in this report. However, laboratory PAH results using both EPA Methods 8310 and 8270 are presented in Section 7.0 of the Data Appendix.

Carcinogenic PAHs detected in the surface water and sediment samples will be discussed where appropriate. The seven carcinogenic PAHs include benzo(a)pyrene, benzo(a) anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene.

PAHs can be formed in combustion processes of hydrocarbons and may be released from oil spills with one of the major sources consisting of industrial activities (Sittig 1985). The major portion of PAHs are strongly bound to suspended particles or sediment (ATSDR 1987 a,c,h). In the vicinity of STF, concentrations of PAHs were

TABLE SW-10

ORGANIC ANALYTICAL RESULTS FOR BACKGROUND SURFACE WATER COMPARED TO WATER QUALITY CRITERIA

Analyte	Freshwater Quality Criteria ($\mu\text{g/L}$) ^(a)		Dry Season Sampling Event (August 1991)			Wet Season Sampling Event (January 1992)		
	Acute or 1-Hour Average ^(b)	Chronic or 4-Day Average ^(c)	Minimum Concentration ($\mu\text{g/L}$)	Maximum Detected Concentration ($\mu\text{g/L}$)	Number of Exceedances of Acute Criteria	Minimum Concentration ($\mu\text{g/L}$)	Maximum Detected Concentration ($\mu\text{g/L}$)	Number of Exceedances of Acute Criteria
PAHs								
Fluorene	NC	NC	U 0.10	0.35	NC	U 0.10	ND	NC
Phenanthrene	30	6.3	U 0.05	0.19	0	U 0.05	0.077	0
Fluoranthene	3,980	NC	U 0.10	2.9	0	U 0.10	0.13	0
Pyrene	NC	NC	U 0.10	1.8	NC	U 0.10	0.11	NC
Benzo(a)anthracene	NC	NC	U 0.10	0.31	NC	U 0.10	ND	NC
Chrysene	NC	NC	U 0.10	0.27	NC	U 0.10	ND	NC
Benzo(b)fluoranthene	NC	NC	U 0.10	0.10	NC	U 0.10	ND	NC
VOCs								
Acetone	NC	NC	J 9.0 J4	J 9.0 J4	NC	U 10.0	ND	NC
Chloroform	28,900	1,240	J 7.0	J 7.0	0	U 10.0	ND	0
Semivolatiles								
bis(2-Ethylhexyl)-phthalate	NC	NC	J 6.0	J 6.0	NC	J 0.9	J 2.0	NC

(a) U.S. EPA (1986).

(b) 1-hour average not exceeded more than once every 3 years on the average.

(c) 4-day average not exceeded more than once every 3 years on the average.

NC No criteria.

ND Not detected.

TABLE SW-11

ORGANIC ANALYTICAL RESULTS FOR RUNON SURFACE WATER COMPARED TO WATER QUALITY CRITERIA

Analyte	Freshwater Quality Criteria (µg/L) ^(a)		Monthly Sampling Events						Storm Sampling Events					
	Acute or 1-Hour Average ^(b)	Chronic or 4-Day Average ^(c)	Location 2500		Location 2501		Number of Exceedences of Acute Criteria		Location 2500		Location 2501		Number of Exceedences of Acute Criteria	
			Minimum Conc. (µg/L)	Maximum Detected Conc. (µg/L)	Minimum Conc. (µg/L)	Maximum Detected Conc. (µg/L)	Location 2500	Location 2501	Minimum Conc. (µg/L)	Maximum Detected Conc. (µg/L)	Minimum Conc. (µg/L)	Maximum Detected Conc. (µg/L)	Location 2500	Location 2501
PAHs														
Naphthalene	2,300	620	U 0.5	0.35	U 0.5	ND	0	0	U 0.5	ND	U 0.5	ND	0	0
Fluorene	NC	NC	U 0.10	0.18	U 0.10	ND	NC	NC	U 0.10	0.36	U 0.10	0.47	NC	NC
Phenanthrene	30	6.3 ^(d)	0.074	1.30	U 0.05	0.98 J4	0	0	0.073	2.5	U 0.05	1.5	0	0
Anthracene	NC	NC	U 0.05	0.13	U 0.05	0.067	NC	NC	J 0.04	0.073	J 0.033	0.19	NC	NC
Fluoranthene	3,980	NC	U 0.10	2.4	U 0.10	3.0	NC	NC	0.32	5.4	U 0.10	4.6	NC	NC
Pyrene	NC	NC	U 0.10	1.7	U 0.10	2.0	NC	NC	0.24	4.2	U 0.10	2.8	NC	NC
Benzo(a)anthracene	NC	NC	U 0.10	0.47	U 0.10	0.35	NC	NC	U 0.10	0.59	U 0.10	0.90	NC	NC
Chrysene	NC	NC	U 0.10	0.78	U 0.10	1.0	NC	NC	J 0.091	2.2	U 0.10	1.40	NC	NC
Benzo(b)fluoranthene	NC	NC	U 0.10	0.62	U 0.10	0.52	NC	NC	J 0.059	2.0	U 0.10	1.1	NC	NC
Benzo(k)fluoranthene	NC	NC	U 0.10	0.40	U 0.10	0.23	NC	NC	U 0.10	0.9	U 0.10	0.55	NC	NC
Benzo(a)pyrene	NC	NC	U 0.10	0.56	U 0.10	0.22	NC	NC	U 0.10	1.0	U 0.10	0.87	NC	NC
Indeno(1,2,3cd)-pyrene	NC	NC	U 0.10	0.53	U 0.10	0.33	NC	NC	U 0.10	1.4	U 0.10	0.92	NC	NC
Dibenzo(a,h)-anthracene	NC	NC	U 0.20	ND	U 0.20	ND	NC	NC	U 0.20	ND	U 0.20	0.2	NC	NC
Benzo(g,h,i)perylene	NC	NC	U 0.10	0.55	U 0.10	0.58	NC	NC	U 0.10	1.0	U 0.10	0.69	NC	NC

(a) U.S. EPA (1986).

(b) 1-hour average not exceeded more than once every 3 years on the average.

(c) 4-day average not exceeded more than once every 3 years on the average.

(d) Proposed criteria (EPA 1992).

NC No criteria.

ND Not detected.

TABLE SW-12

ORGANIC ANALYTICAL RESULTS FOR ONSITE SURFACE WATER COMPARED TO WATER QUALITY CRITERIA

Analyte	Freshwater Quality Criteria ($\mu\text{g/L}$)		Transitional Season Sampling Event (April 1991)			Dry Season Sampling Event (August 1991)			Wet Season Sampling Event (January 1992)		
	Acute or 1-Hour Average ^(b)	Chronic or 4-Day Average ^(c)	Minimum Conc. ($\mu\text{g/L}$)	Maximum Detected Conc. ($\mu\text{g/L}$)	Number of Exceedances of Acute Criteria	Minimum Conc. ($\mu\text{g/L}$)	Maximum Detected Conc. ($\mu\text{g/L}$)	Number of Exceedances of Acute Criteria	Minimum Conc. ($\mu\text{g/L}$)	Maximum Detected Conc. ($\mu\text{g/L}$)	Number of Exceedances of Acute Criteria
PAHs											
Fluorene	NC	NC	U 0.02	ND	NC	U 0.10	0.45	NC	U 0.10	0.21	NC
Phenanthrene	30	6.3	U 0.01	ND	0	U 0.05	3.9	0	U 0.05	2.1	0
Anthracene	NC	NC	0.01	0.01	NC	U 0.05	0.061	NC	U 0.05	0.14	NC
Fluoranthene	3,980	NC	U 0.02	ND	0	U 0.10	8.2	0	U 0.10	7.7	0
Pyrene	NC	NC	U 0.01	ND	NC	U 0.10	7.5	NC	U 0.10	5.0	NC
Benzo(a)-anthracene	NC	NC	U 0.01	ND	NC	U 0.10	1.5	NC	U 0.10	0.97	NC
Chrysene	NC	NC	U 0.01	ND	NC	U 0.10	4.4	NC	U 0.10	1.3	NC
Benzo(b)-fluoranthene	NC	NC	U 0.01	ND	NC	U 0.10	3.9	NC	U 0.10	2.0	NC
Benzo(k)-fluoranthene	NC	NC	U 0.01	ND	NC	U 0.10	2.1	NC	U 0.10	1.2	NC
Benzo(a)pyrene	NC	NC	U 0.01	ND	NC	U 0.10	3.8	NC	U 0.10	2.0	NC
Indeno(1,2,3cd)-pyrene	NC	NC	U 0.01	ND	NC	U 0.10	2.0	NC	U 0.10	1.5	NC
Dibenzo(a,h)-anthracene	NC	NC	U 0.02	ND	NC	U 0.20	ND	NC	U 0.20	1.0	NC
Benzo(g,h,i)-perylene	NC	NC	U 0.02	ND	NC	U 0.10	3.7	NC	U 0.10	1.1	NC
VOCs											
Methylene Chloride	NC	NC	U 2.0 UJ	ND	NC	JB 4.0 UJ	ND	NC	JB 3.0 UJJ	8.0 J4	NC
Chloroform	28,900	1,240	U 10.0	ND	0	J 1.0 J	5.0	0	J 2.0 J	2.0	0
Toluene	17,500	NC	U 10.0	ND	0	J 2.0 J	7.0	0	U 10.0	ND	0

TABLE SW-12

ORGANIC ANALYTICAL RESULTS FOR ONSITE SURFACE WATER COMPARED TO WATER QUALITY CRITERIA

Analyte	Freshwater Quality Criteria (µg/L)		Transitional Season Sampling Event (April 1991)			Dry Season Sampling Event (August 1991)			Wet Season Sampling Event (January 1992)		
	Acute or 1-Hour Average ^(b)	Chronic or 4-Day Average ^(c)	Minimum Conc. (µg/L)	Maximum Detected Conc. (µg/L)	Number of Exceedances of Acute Criteria	Minimum Conc. (µg/L)	Maximum Detected Conc. (µg/L)	Number of Exceedances of Acute Criteria	Minimum Conc. (µg/L)	Maximum Detected Conc. (µg/L)	Number of Exceedances of Acute Criteria
Semivolatiles (excluding PAHs)											
N-nitrosodi-phenylamine	NC	NC	U 10.0	ND	NC	U 10.0	ND	NC	U 10.0	J 1.0	NC
4-Methylphenol	NC	NC	U 10.0	ND	NC	J 4.0	J 4.0	NC	J 0.7	J 0.7	NC
4-Nitrophenol	230 ^(d)	NC	U 25.0	ND	0	U 25.0	ND	0	J 1.0 J4	J 2.0 J4	0
Diethylphthalate	NC	NC	U 10.0	ND	NC	U 10.0	ND	NC	J 0.6	J 0.9	NC
Pentachloro-phenol	7.3 (2502) ^(e) 5.3 (2503)	4.9 (2502) ^(f) 3.5 (2503)	U 25.0	ND	0	U 25	ND	0	J 5.0	J 6.0	0
Butylbenzyl-phthalate	NC	NC	U 10.0	ND	NC	U 10.0	ND	NC	J 0.5	J 0.6	NC
bis(2-Ethylhexyl)-phthalate	NC	NC	U 10.0	ND	NC	J 5.0	55.0	NC	J 0.6	37.0	NC
Di-n-octylphthalate	NC	NC	U 10.0	ND	NC	U 10.0	ND	NC	J 0.6 J4	J 0.7	NC

(a) U.S. EPA (1986).
(b) 1-hour average not exceeded more than once every 3 years on the average.
(c) 4-day average not exceeded more than once every 3 years on the average.
(d) Criteria based on total nitrophenols.
(e) 1-hour average at Locations 2502 and 2503 where pentachlorophenol was detected at less than calculated criteria. Criteria based on equation $e^{[1.005(\text{pH})-4.893]}$.
(f) 4-day average at Locations 2502 and 2503 where pentachlorophenol was detected at less than calculated criteria. Criteria based on equation $e^{[1.005(\text{pH})-5.290]}$.
NC No criteria.
ND Not detected.

TABLE SW-13

ORGANIC ANALYTICAL RESULTS FOR RUNOFF SURFACE WATER COMPARED TO WATER QUALITY CRITERIA

Analyte	Freshwater Quality Criteria ($\mu\text{g/L}$) ^(a)		Biweekly Sampling Events		Storm Sampling Event (1/28/92)	Number of Exceedances of Acute Criteria
	Acute or 1-Hour Average ^(b)	Chronic or 4-Day Average ^(c)	Minimum Conc. ($\mu\text{g/L}$)	Maximum Detected Conc. ($\mu\text{g/L}$)		
PAHs						
Phenanthrene	30	6.3	U 0.05	ND	0.087	0
Fluoranthene	3,980	NC	U 0.10	ND	0.18	0
Pyrene	NC	NC	U 0.10	U 0.10	0.13	NC
Semivolatiles						
Pentachlorophenol	5.54 ^(d)	3.50 ^(e)	U 25.0	J 0.7	J 0.6	0
Bis(2-ethylhexyl)- phthalate	NC	NC	J 0.7	75.0	J 0.5 J4	NC

(a) U.S. EPA (1986).

(b) 1-hour average not exceeded more than once every 3 years on the average.

(c) 4-day average not exceeded more than once every 3 years on the average.

(d) 1-hour average based on pH of 6.5 for biweekly sample collected on 11/27/91.

(e) 4-day average based on pH of 6.5 for biweekly sample collected on 11/27/91.

NC No criteria.

ND Not detected.

detected in the sediment [i.e., 7.4 mg/kg (sum of fluoranthene, phenanthrene, and pyrene)], but not the surface water (Lum and Turney 1985).

Background information on concentrations of PAHs detected in the environment is discussed for specific compounds. The information was compared with detected PAH concentrations in runoff surface water, onsite surface water and sediment, and runoff surface water samples to identify natural or other sources of the PAHs.

- Anthracene is ubiquitous in the aquatic environment and occurs at a median concentration of $< 10 \mu\text{g/L}$. Anthracene has the strong ability of adsorption to suspended particle matter and sediment in water (U.S. EPA 1987a).
- The major portion of benzo(a)anthracene is strongly bound to suspended particles or bed sediments (ATSDR 1987a).
- Fluoranthene was detected at concentrations ranging from $6.2 \mu\text{g/kg}$ to $2,500 \mu\text{g/kg}$ in sediment and at $0.03 \mu\text{g/L}$ in surface water collected in the Leach Creek area (Lum and Turney 1985).
- Sources of naphthalene include fugitive emissions and exhaust connected with its use in gasoline. Releases to water are lost fairly rapidly due to volatilization, photolysis, biodegradation, and adsorption to sediment. When adsorbed to sediment, the biodegradation occurs at a much more rapid rate than in the water. Concentrations have been found in natural waters up to $2 \mu\text{g/L}$ and in industrialized areas up to $10 \mu\text{g/L}$. Surficial sediment of Boston Harbor near stormwater runoff and sewage outfalls ranged from less than $10 \mu\text{g/kg}$ to $43,628 \mu\text{g/kg}$ dry weight (Howard 1989).

- Phenanthrene was detected in sediment from the Leach Creek area at concentrations ranging from 30 $\mu\text{g/kg}$ to 1,800 $\mu\text{g/kg}$ (Lum and Turney 1985).
- Pyrene was detected at concentrations ranging from 14 $\mu\text{g/kg}$ to 3,100 $\mu\text{g/kg}$ in sediment and at 0.03 $\mu\text{g/L}$ in surface water collected in the Leach Creek area (Lum and Turney 1985).

5.2.1.1 Background. PAH analyses were performed on background samples collected during the wet and dry season sampling events. PAHs were detected in background samples collected during the dry season at Locations 2500 and 2541 (see Table SW-10). PAHs detected in the samples collected from these two locations included phenanthrene, fluoranthene, pyrene, and chrysene. In addition, fluorene, benzo(a)anthracene, and benzo(b)fluoranthene were detected in the sample collected from Location 2541 only.

PAHs were detected in samples collected during the wet season at background Locations 2500 and 2542. Phenanthrene and fluoranthene were detected in the sample collected from Location 2500. Fluoranthene and pyrene were detected in the sample collected from Location 2542.

Carcinogenic PAHs [chrysene, benzo(b)fluoranthene, and benzo(a)anthracene] were detected in samples collected during the dry season at background Locations 2500 and 2541. The summation of the carcinogenic PAHs concentrations was 0.49 $\mu\text{g/L}$ and 0.93 $\mu\text{g/L}$ for background Locations 2500 and 2541, respectively.

Carcinogenic PAHs were not detected in samples collected during the wet season at background locations. AFWQC was not exceeded for PAHs compounds (phenanthrene and fluoranthene) that were detected in background surface water samples collected during this investigation. Generally, PAHs concentrations detected in dry season samples were greater than the concentrations detected in the wet season samples.

5.2.1.2 Runon. PAHs were detected in all surface water runon samples collected at Locations 2500 and 2501 (see Table SW-11). Fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene and benzo(g,h,i)perylene were the most frequently detected PAHs in surface water samples collected from the two locations. All seven carcinogenic PAHs were detected in the surface water runon samples collected at Locations 2500 and 2501. Six of the seven were detected in the monthly runon samples collected at Locations 2500 and 2501.

In monthly surface water runon samples, individual PAH compounds were typically detected at concentrations below 1 $\mu\text{g/L}$, except phenanthrene, fluoranthene, pyrene and chrysene, which were occasionally detected at concentrations between 1 $\mu\text{g/L}$ and 3 $\mu\text{g/L}$.

AFWQC for naphthalene, phenanthrene, and fluoranthene were not exceeded for monthly runon samples.

PAH concentrations detected in stormwater runon samples were nearly always higher than concentrations detected in the monthly surface water runon samples (see Appendix SW-B). In addition, PAH compounds were detected more frequently in the stormwater runon samples as compared to the monthly runon surface water samples.

For monthly surface water runon samples, concentrations of detected PAH compounds were similar for Locations 2500 and 2501. For stormwater runon samples, the concentrations of detected PAH compounds were typically higher at Location 2500 when compared to Location 2501. In both monthly and stormwater runon samples, PAH compounds were detected more frequently at Location 2500 than Location 2501.

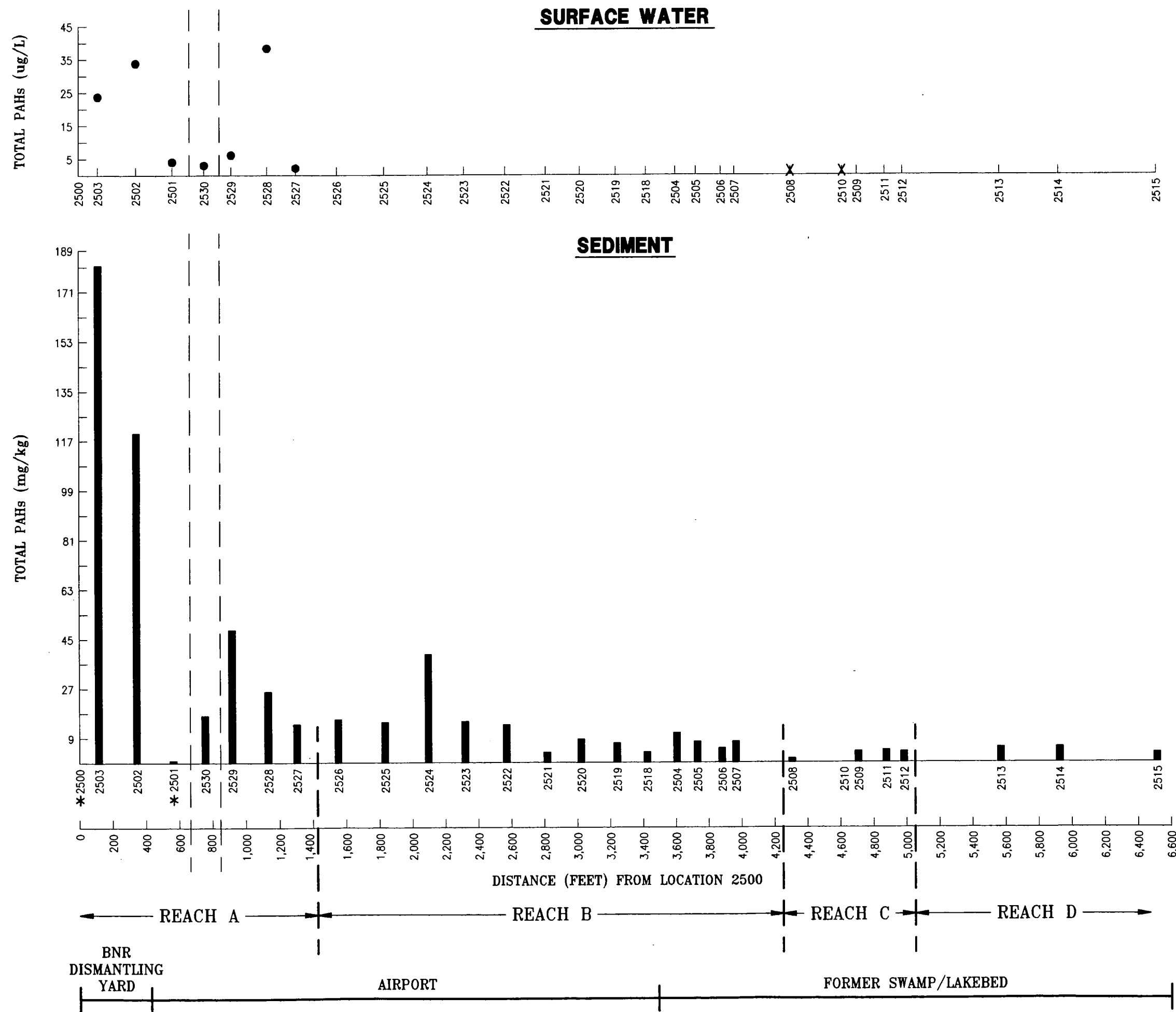
Seasonal variation of runon total and carcinogenic PAHs is not apparent at Locations 2500 and 2501. The number of detected PAHs in the runon samples was greater than the background surface water PAHs detected. The runon samples collected represent the urban surface water runoff from residential, commercial, and light industry; this runoff has been documented to contain detected concentrations of PAHs.

5.2.1.3 Onsite Surface Water. PAH analyses were performed on onsite surface water and sediment samples collected during the three seasonal events (see Table SW-12).

Concentrations of PAHs in onsite surface water and sediment samples collected during the transitional season are presented in Table SW-12. Anthracene ($0.01 \mu\text{g/L}$) at Location 2506 was the only PAH detected in all surface water samples collected during the transitional season. No WQC exists for anthracene.

Concentrations of PAHs in onsite surface water and sediment samples collected during the dry season are presented as total and carcinogenic PAHs in Appendix SW-D and Figures SW-44 and 45, respectively. PAHs were detected in all onsite surface water samples (except from Locations 2508 and 2510) collected during the dry season. Naphthalene, acenaphthylene, acenaphthene, and dibenzo(a,h)anthracene were not detected in any samples. The remaining PAHs were detected at concentrations that ranged from $0.056 \mu\text{g/L}$ (anthracene at Location 2530) to $8.2 \mu\text{g/L}$ (fluoranthene at Location 2528).

Total PAHs and carcinogenic PAHs were primarily detected in onsite surface water samples collected during the dry season in Reach A. Concentrations of total PAHs ranged from $1.6 \mu\text{g/L}$ (Locations 2508 and 2510) to $39 \mu\text{g/L}$ (Location 2528). Carcinogenic PAHs ranged from $0.40 \mu\text{g/L}$ (Locations 2508 and 2510) to $14 \mu\text{g/L}$ (Location 2528). The most frequently detected (i.e., greater than 50 percent of the sampled locations) PAHs include phenanthrene, fluoranthene, pyrene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, and benzo(a)pyrene.



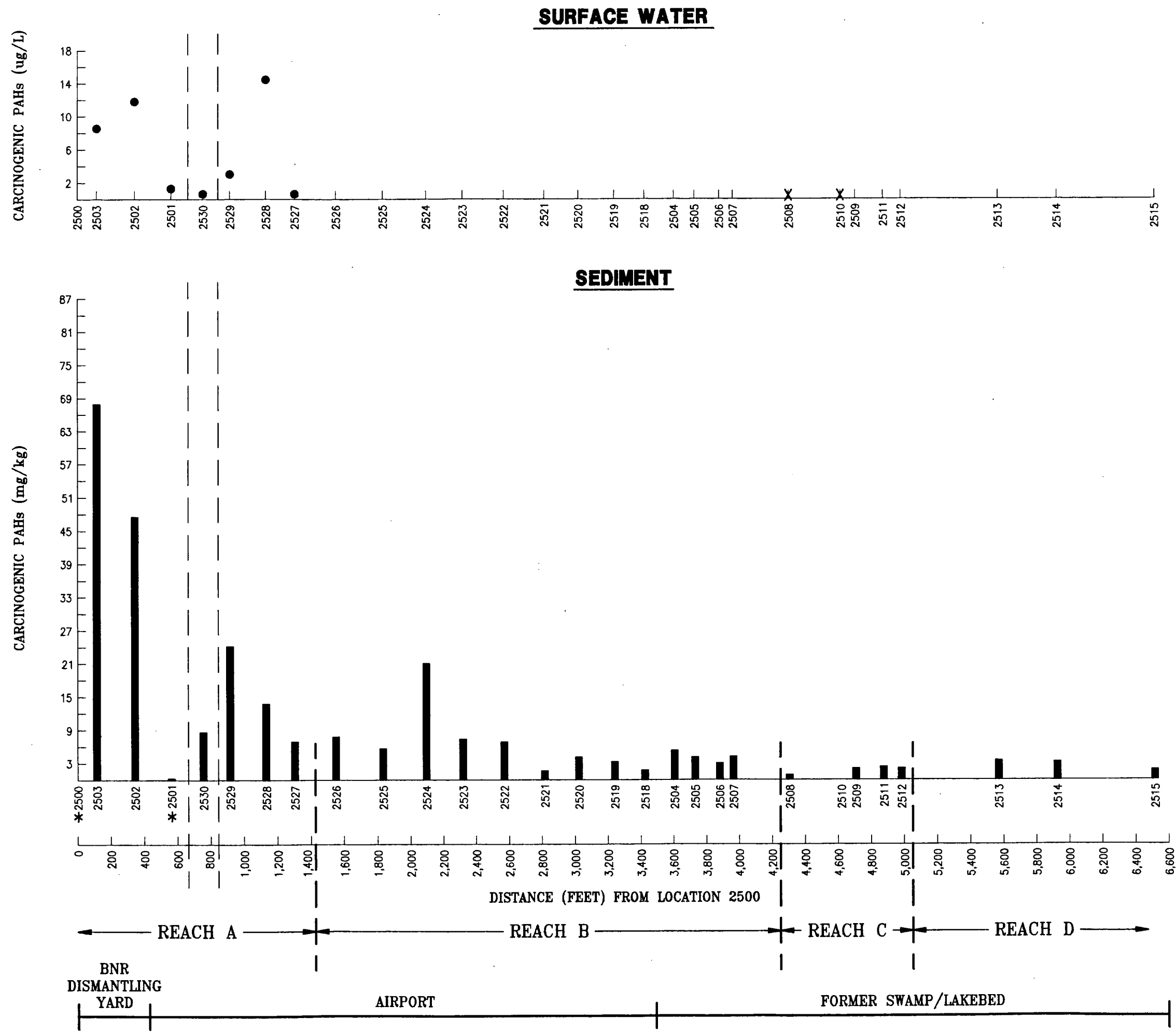
Kennedy/Jenks Consultants

SOUTH TACOMA FIELD
TACOMA, WA

**TOTAL PAH CONCENTRATIONS FOR
SURFACE WATER AND SEDIMENT
SAMPLES (DRY SEASON, AUGUST 1991)**

916055.24/P2SK056

FIGURE SW-44



LEGEND

- SURFACE WATER CONCENTRATION
- DRY-WEIGHT NORMALIZATION
- X 1/2 DETECTION LIMIT
- * SURFACE WATER RUNON LOCATION

Kennedy/Jenke Consultants

SOUTH TACOMA FIELD
TACOMA, WA

**TOTAL CARCINOGENIC PAH CONCENTRATIONS
FOR SURFACE WATER AND SEDIMENT
SAMPLES (DRY SEASON, AUGUST 1991)**

916055.24/P2SK054

FIGURE SW-45

The AFWQC for individual PAHs was not exceeded for onsite (dry season) surface water samples.

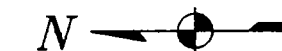
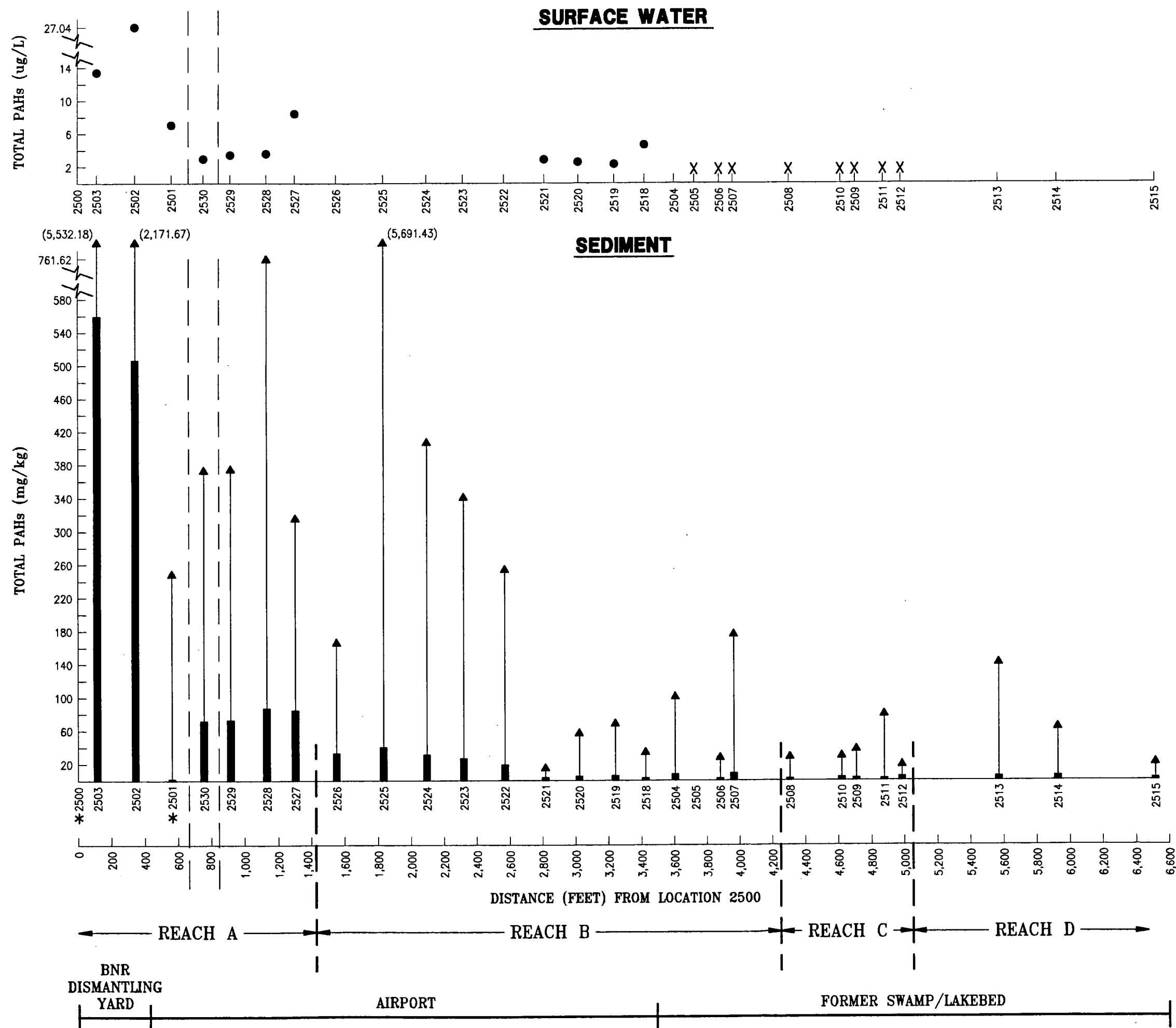
Concentrations of onsite PAHs in surface water and sediment samples collected during the wet season are presented as total and carcinogenic PAHs in Appendix SW-D and Figures SW-46 and 47, respectively. PAHs were detected in 12 of 24 surface water samples collected during the wet season. Detected concentrations ranged from 0.052 $\mu\text{g/L}$ (anthracene at Location 2503) to 7.7 $\mu\text{g/L}$ (fluoranthene at Location 2502). The AFWQC for individual PAHs was not exceeded at any location.

Total PAHs and carcinogenic PAHs were primarily detected in onsite surface water samples collected during the wet season in Reach A. Concentrations of total PAHs for locations where PAHs were detected ranged from 1.6 $\mu\text{g/L}$ (Location 2511) to 27 $\mu\text{g/L}$ (Location 2502). Concentrations of carcinogenic PAHs ranged from 0.40 $\mu\text{g/L}$ (Location 2511) to 9.8 $\mu\text{g/L}$ (Location 2502). The most frequently detected (i.e., greater than 50 percent of the sampled locations) PAHs include phenanthrene, fluoranthene, pyrene, chrysene, and benzo(b)fluoranthene.

Maximum PAH concentrations for onsite surface water samples were similar in the dry and wet seasons.

Analytical results from runoff surface water samples collected showed all PAHs were detected at concentrations ranging from undetected to 5.4 $\mu\text{g/L}$ and up to a total PAH concentration of 22.09 $\mu\text{g/L}$ (fluoranthene at Location 2500 during the storm event). Onsite total PAH concentrations were slightly higher than the runoff concentrations.

5.2.1.4 Onsite Sediment. PAHs were detected in onsite sediment samples collected from Locations 2506, 2509, and 2511 during the transitional season. Detected PAHs include phenanthrene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno-



CARCINOGENIC PAHs (ug/L)

SURFACE WATER

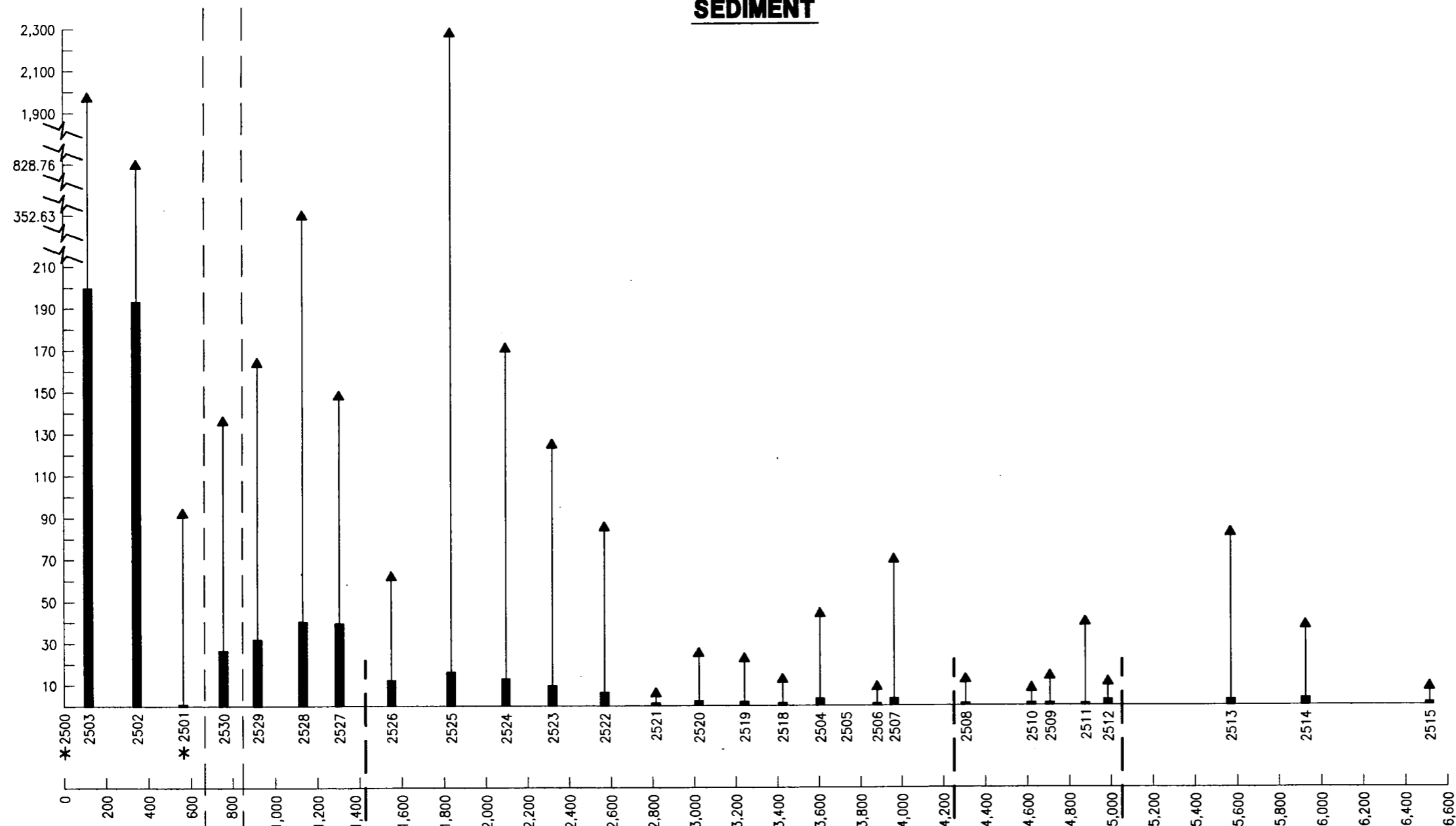
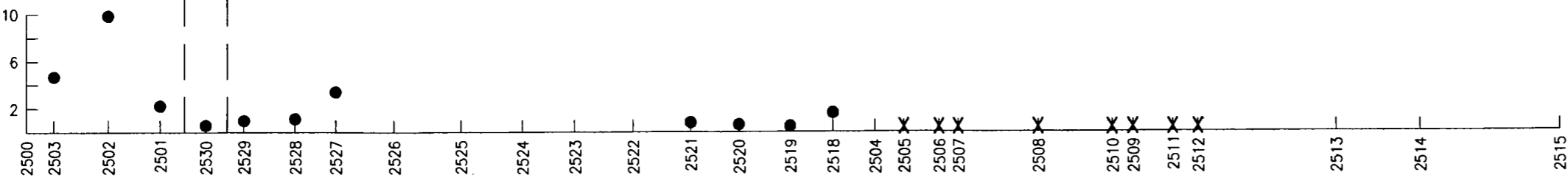


CARCINOGENIC PAHs (mg/kg)

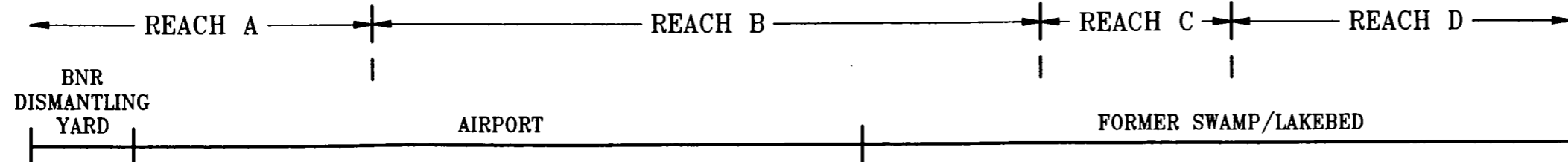
SEDIMENT

LEGEND

- SURFACE WATER CONCENTRATION
- DRY-WEIGHT NORMALIZATION
- ▲ TOTAL ORGANIC MATTER NORMALIZATION
- X 1/2 DETECTION LIMIT
- * SURFACE WATER RUNON LOCATION



DISTANCE (FEET) FROM LOCATION 2500



Kennedy/Jenks Consultants

SOUTH TACOMA FIELD
TACOMA, WA

**TOTAL CARCINOGENIC PAH CONCENTRATIONS
FOR SURFACE WATER AND SEDIMENT
SAMPLES (WET SEASON, JANUARY 1992)**

916055.24/P2SK055

FIGURE SW-47

(1,2,3-cd)pyrene, and benzo(g,h,i)perylene. Detected concentrations ranged from 0.031 mg/kg [benzo(a)anthracene at Location 2511] to 0.27 mg/kg (pyrene at Location 2506).

Total PAHs were detected three of five onsite sediment samples collected during the transitional season (all locations except the two samples collected from Location 2516). Detected concentrations ranged from 1.2 mg/kg at Location 2511 to 2.1 mg/kg at Location 2506. Carcinogenic PAHs were also detected in the same three onsite sediment samples collected during the transitional season. Concentrations ranged from 0.42 mg/kg at Location 2511 to 0.78 mg/kg at Location 2506. Total and carcinogenic PAHs were detected in sediment samples collected from Reaches B and C.

PAHs were detected in nearly all onsite sediment samples collected during the dry season. Exceptions include samples collected from Location 2510 (all data were rejected) and one of the samples from Location 2516. Detected concentrations ranged from 0.013 mg/kg (pyrene at Location 2516) to 41 mg/kg (fluoranthene at Location 2503; this concentration was estimated and diluted). Total PAH concentrations ranged from 0.27 mg/kg at Location 2516 to 180 mg/kg at Location 2503. Carcinogenic PAHs ranged from 0.47 mg/kg at Location 2516 to 68 mg/kg at Location 2503.

Dry weight concentrations of total and carcinogenic PAHs in onsite samples collected during the dry season are relatively elevated [maximum values are 180 mg/kg (total PAHs) and 68 mg/kg (carcinogenic PAHs) both at Location 2503] in the northern section of Reach A and then begin to decrease rapidly in the southern section of Reach A and the northern section of Reach B. In the southern section of Reach B and all of Reaches C and D, concentrations remain relatively low (i.e., below 9 mg/kg).

PAHs were detected in all onsite sediment samples collected during the wet season. Concentrations ranged from 0.014 mg/kg [benzo(a)pyrene at Location

2516] to 130 mg/kg (fluoranthene at Location 2503). Total PAHs were detected in all wet season samples. Total PAH concentrations ranged from 0.49 mg/kg at Location 2516 to 560 mg/kg at Location 2503. Carcinogenic PAHs concentrations ranged from 0.076 mg/kg at Location 2516 to 200 mg/kg at Location 2503.

Dry weight concentrations of total PAHs were the most elevated in the northern section of Reach A, but decreased rapidly and remained low throughout the remainder of the surface water channel. When normalized to percent fine-grain material, elevated concentrations were detected in Reaches A and B at the locations of elevated dry weight concentrations. Similar to the pattern described for dry weight concentrations, the most elevated normalized concentrations were detected in Reach A and the northern section of Reach B, but then the concentrations decreased rapidly and remained relatively low throughout the remainder of the surface water channel.

Dry weight concentrations of carcinogenic PAHs showed a pattern similar to that discussed for total PAHs (i.e., concentrations were the most elevated in Reach A and the northern section of Reach B, but then quickly decreased and remained relatively low throughout the remainder of the surface water channel).

5.2.1.5 Runoff. PAH analyses were performed on surface water runoff samples collected during biweekly and storm sampling events (see Table SW-13).

Phenanthrene, fluoranthene, and pyrene were detected at concentrations less than 0.2 µg/L in the stormwater runoff sample collected at Location 2515.

The PAHs concentrations detected in the runoff storm water sample were within the concentrations detected in the runoff surface water samples.

5.2.2 VOCs

VOC analyses were performed on background, onsite, and runoff surface water samples and onsite sediment samples collected during this investigation (i.e., runoff samples were not analyzed for VOCs). VOCs detected background, onsite, and runoff samples are discussed in this section. VOC analyses were performed using EPA CLP methods.

Background information on concentrations of VOCs detected in the environment are discussed for specific compounds detected in the surface water samples collected at the background locations. This information is compared with detected VOC concentrations in onsite surface water and sediment and runoff surface water samples to identify natural or other sources of the VOCs.

- Acetone is a widely used solvent and is present in urbanized areas. If released to water, the acetone will primarily volatilize or biodegrade. Sorption to sediment should not be significant.
- Sources of benzene include fugitive emissions and exhaust connected with its use in gasoline. Benzene in water tends to volatilize quickly and is not expected to significantly adsorb to sediment or suspended particles. Average surface water concentrations throughout the U.S. have been reported at 5.4 $\mu\text{g/L}$. Median sediment concentrations reported from the U.S. EPA STORET databases were less than 5 $\mu\text{g/kg}$ (Howard 1990).
- Chloroform is associated with industry as a solvent and can be released to the environment from auto exhaust. If released to water, chloroform will volatilize quickly without a significant amount adsorbing to sediment. Chloroform is adsorbed most strongly to peat moss and less strongly to clays. Chloroform has been detected in U.S. surface water at a median concentration of 0.30 $\mu\text{g/L}$ and as high as 0.37 $\mu\text{g/L}$ and in sediment at a

median concentration of less than 5 $\mu\text{g/kg}$ with a maximum concentration of 18 $\mu\text{g/kg}$ (ATSDR 1989a; Howard 1990).

- Chloromethane (methyl chloride) is emitted as a fugitive emissions, as a solvent, and as a by-product in many industries. If released to the water, it will primarily be lost to volatilization. Median concentrations in surface water in the U.S. are less than 10 $\mu\text{g/L}$ (Howard 1990).
- Sources of ethylbenzene include fugitive emissions and exhaust connected with its use in gasoline. When released to water, ethylbenzene will evaporate fairly rapidly with some adsorption by sediment. Ethylbenzene has been detected in surface water at a median value of less than 5.0 $\mu\text{g/L}$ and in sediment at a median of 5 mg/kg dry weight (Howard 1989).
- Sources of toluene are primarily from volatilization of petroleum fuels, solvents, thinners, and from motor vehicle exhaust. The presence in water is reduced by volatilization and biodegradation. The median concentration in U.S. surface water is 7.5 $\mu\text{g/L}$. The median concentration in U.S. sediment is 5 $\mu\text{g/kg}$ (ATSDR 1988f). Concentrations of toluene were detected at 12 $\mu\text{g/L}$ and 62 $\mu\text{g/L}$ in surface water and ranged from 2 $\mu\text{g/kg}$ to 130 $\mu\text{g/kg}$ in sediment collected in the Leach Creek area (Lum and Turney 1985).
- Methylene chloride is a widely used solvent. Methylene chloride usually volatilizes from surface water with little adsorption to sediment or suspended particles. Concentrations found in ambient water ranged from undetected to 120 $\mu\text{g/L}$. Sediment concentrations ranged from 427 $\mu\text{g/kg}$ to 433 $\mu\text{g/kg}$ (ATSDR 1987j).
- 1,1,1-Trichloroethane is widely used in industry as a degreaser and metal cleaner. Concentrations in surface water will decrease almost entirely to volatilization. 1,1,1-Trichloroethane will adsorb to peat moss and a little

less to clays. Concentrations detected in U.S. surface water ranged from a median of 0.2 $\mu\text{g/L}$ for 105 cities to 10 $\mu\text{g/L}$ for industrial areas. Sediment concentrations have been detected at a range of 0.039-2.6 $\mu\text{g/kg}$ near industrial areas (Howard 1990). Trichloroethane was detected in a surface water sample collected in the Leach Creek area at 5 $\mu\text{g/L}$ (Lum and Turney 1985).

- Sources of xylenes include fugitive emissions and exhaust connected with its use in gasoline and industrial uses such as solvents. In surface water, losses tend to be due to volatilization with some adsorption to sediment. Xylenes have been detected in unspecified sediment at 500 $\mu\text{g/kg}$ and were a major VOC present in sediment (Howard 1990).

5.2.2.1 Background. VOCs analyses were performed on background samples collected during the wet and dry season sampling events. VOCs detected in the background samples collected during the dry season included acetone (9 $\mu\text{g/L}$) at Location 2541 and chloroform (7 $\mu\text{g/L}$) at Location 2500. No VOCs were detected in the background samples collected during the wet season event. AFWQC was not exceeded for chloroform and no WQC exists for acetone.

5.2.2.2 Onsite Surface Water. VOCs analyses were performed on onsite samples collected during the transitional, dry and wet season sampling events. Concentrations of VOCs detected in onsite surface water and sediment samples collected during the transitional season are presented in Appendix SW-D. VOCs were not detected in onsite surface water during this season.

Concentrations of VOCs in onsite surface water collected during the dry season are presented in Appendix SW-D and Table SW-12. The only detected VOCs were chloroform and toluene. Chloroform was detected at four locations, all in Reach A. These concentrations (all estimated) ranged from 1 $\mu\text{g/L}$ at Location 2528 to 5 $\mu\text{g/L}$ at Location 2503. Toluene was detected at five locations. Concentrations ranged from 2 $\mu\text{g/L}$ at Locations 2529 and 2530 to 7 $\mu\text{g/L}$ at Location 2502. Acetone

and chloroform were each detected at estimated concentrations (9 $\mu\text{g/L}$ and 7 $\mu\text{g/L}$, respectively) in background samples collected during the dry season.

Concentrations of VOCs in onsite surface water collected during the wet season are presented in Appendix SW-D and Table SW-12. Methylene chloride was detected at Locations 2505 and 2510 and chloroform was detected at 2 $\mu\text{g/L}$ at Location 2503 in Reach A.

5.2.2.3 Onsite Sediment. Concentrations of VOCs in onsite sediment samples collected during the transitional season are presented in Appendix SW-D. VOCs were detected in two onsite sediment samples. VOCs detected at Location 2506 include chloroform, (140 $\mu\text{g/kg}$), toluene (2,300 $\mu\text{g/kg}$), and xylene (33 $\mu\text{g/kg}$). 1,1,1-Trichloroethane was detected at Location 2516 at a concentration of 22 mg/kg .

Concentrations of VOCs in onsite sediment samples collected during the dry season are presented in Appendix SW-D. Nine VOCs (chloromethane, methylene chloride, acetone, 2-butanone, toluene, benzene, 2-hexanone, ethyl benzene, and xylenes) were detected in dry season sediment samples. Detected concentrations ranged from 7 $\mu\text{g/kg}$ (acetone at Location 2505) to 6,400 $\mu\text{g/kg}$ (toluene at Location 2527). VOCs were detected in onsite sediment samples collected throughout the surface water channel.

Concentrations of VOCs in onsite sediment samples collected during the wet season are presented in Appendix SW-D. Six VOCs (chloromethane, methylene chloride, acetone, toluene, ethyl benzene, and xylenes) were detected in sediment samples collected during the wet season. Detected concentrations ranged from 5 $\mu\text{g/kg}$ (toluene at Location 2515) to 800 $\mu\text{g/kg}$ (acetone at Location 2504). Methylene chloride and acetone were detected in most samples; however, most of the detected compounds were also detected in the laboratory blanks. Detection of methylene chloride and acetone is apparently attributable to laboratory contamination.

5.2.2.4 Runoff. VOCs analyses were performed on runoff surface water samples collected biweekly and during storm events. VOCs were not detected in the runoff surface water samples collected at Location 2515.

5.2.2.5 VOC TICs

Database printouts for tentatively identified compounds (TICs) detected in samples collected during this investigation are provided in Section 7.0 of the Data Appendix.

Background. One volatile TIC was reported by the laboratory for background samples collected during the dry season. A volatile TIC (hexane) was detected at 6 $\mu\text{g/L}$ in samples collected at Locations 2542 and 2543 during the dry season sampling event. No TICs were detected in the wet season sampling event.

Onsite Surface Water. Volatile TICs were detected in onsite surface water and sediment samples collected during the dry and wet season and are summarized in Table SW-14. Only a few volatile TICs were identified in onsite surface water samples collected during the dry season. Concentrations of volatile TICs for surface water samples collected during the dry season ranged from 6 $\mu\text{g/L}$ for hexane at Locations 2501 and 2502 to 72 $\mu\text{g/L}$ for 2-hexanamine at Location 2527. The most commonly detected TICs were hexane and 1,1,2-trichloro-1,2-ethane. Unknown TICs were also detected.

Concentrations of volatile TICs for onsite surface water samples collected during the wet season ranged from 6 $\mu\text{g/L}$ for dodecane at Location 2520 to 67 $\mu\text{g/L}$ for tetradecane, also at Location 2520. The most commonly detected TICs include pentadecane and tetradecane. A few unknown TICs were detected.

Onsite Sediment. Concentrations of volatile TICs for onsite sediment samples collected during the dry season ranged from 16 $\mu\text{g/kg}$ for 4-ethyl-2,2,6,6-tetraheptane at Location 2501 to 2,500 $\mu\text{g/kg}$ for undecane at Location 2502.

TABLE SW-14

**VOLATILE TICS DETECTED IN
ONSITE SURFACE WATER AND SEDIMENT SAMPLES**

Reach	Onsite Location Number	Transitional Season Event (April 1991)				Dry Season Event (August 1991)				Wet Season Event (January 1992)			
		Surface Water		Sediment		Surface Water		Sediment		Surface Water		Sediment	
		No. of Detects	Range (µg/L)	No. of Detects	Range (µg/kg)	No. of Detects	Range (µg/L)	No. of Detects	Range (µg/kg)	No. of Detects	Range (µg/L)	No. of Detects	Range (µg/kg)
A	2501	NS ^(a)	--	NS	--	1	6	1	16	1	7	1	18
A	2502	NS	--	NS	--	3	6-9	7	280-1,300	0	--	10	190-1,700
A	2503	NS	--	NS	--	1	7	7	380-1,700	1	10	10	190-1,400
A	2527	NS	--	NS	--	2	7-72	7	140-2,000	1	22	4	71-130
A	2528	NS	--	NS	--	0	--	1	100	0	--	4	63-250
A	2529	NS	--	NS	--	0	--	1	120	1	9	5	110-400
A	2530	NS	--	NS	--	0	--	4	66-79	1	7	5	90-260
B	2504	NS	--	NS	--	NS	--	0	--	NS	--	0	--
B	2506	0	--	0	--	NS	--	0	--	0	--	0	--
B	2507	NS	--	NS	--	NS	--	1	21	0	--	0	--
B	2518	NS	--	NS	--	NS	--	0	--	2	8-19	0	--
B	2519	NS	--	NS	--	NS	--	0	--	1	38	0	--
B	2520	NS	--	NS	--	NS	--	0	--	2	6-67	0	--
B	2521	NS	--	NS	--	NS	--	0	--	1	19	0	--
B	2522	NS	--	NS	--	NS	--	0	--	NS	--	1	33
B	2523	NS	--	NS	--	NS	--	0	--	NS	--	0	--

TABLE SW-14

**VOLATILE TICS DETECTED IN
ONSITE SURFACE WATER AND SEDIMENT SAMPLES**

Reach	Onsite Location Number	Transitional Season Event (April 1991)				Dry Season Event (August 1991)				Wet Season Event (January 1992)			
		Surface Water		Sediment		Surface Water		Sediment		Surface Water		Sediment	
		No. of Detects	Range ($\mu\text{g/L}$)	No. of Detects	Range ($\mu\text{g/kg}$)	No. of Detects	Range ($\mu\text{g/L}$)	No. of Detects	Range ($\mu\text{g/kg}$)	No. of Detects	Range ($\mu\text{g/L}$)	No. of Detects	Range ($\mu\text{g/kg}$)
B	2524	NS	--	NS	--	NS	--	2	100-180	NS	--	0	--
B	2525	NS	--	NS	--	NS	--	0	--	NS	--	0	--
B	2526	NS	--	NS	--	NS	--	3	65-160	NS	--	2	60-210
C	2505	NS	--	NS	--	NS	--	0	--	0	--	NS	--
C	2508	NS	--	NS	--	1	7	0	--	0	--	0	--
C	2509	0	--	0	--	NS	--	0	--	0	--	0	--
C	2510	NS	--	NS	--	1	8	0	--	0	--	0	--
C	2511	0	--	0	--	NS	--	0	--	1	10	0	--
C	2512	NS	--	NS	--	NS	--	0	--	0	--	0	--
D	2513	NS	--	NS	--	NS	--	0	--	NS	--	0	--
D	2514	NS	--	NS	--	NS	--	0	--	NS	--	0	--
D	2515	NS	--	NS	--	NS	--	0	--	NS	--	0	--
NA ^(b)	2516	0	--	0	--	NS	--	0	--	0	--	1	46

(a) NS = No sample collected.

(b) NA = Not applicable (Location 2516 is outside surface water channel).

Volatile TICs primarily consist of nonchlorinated branched and unbranched alkanes with a few alenes, alcohols, aldehydes, and ketones. The length of the carbon chains ranged from 5 to 13. A few unknown TICs were also detected.

Concentrations of volatile TICs for onsite sediment samples collected during the wet season ranged from 18 $\mu\text{g/kg}$ for 3,7-dimethyl-nonane at Location 2501 to 1,700 $\mu\text{g/kg}$ for dodecane at Location 2502. Most TICs were for non-chlorinated branched and unbranched alkanes with a few alkenes, alcohols, and ketones. The length of the carbon chains primarily ranged from 9 to 13. Very few unknown TICs were detected.

Runoff. No volatile TICs were detected in runoff biweekly and stormwater samples collected at Location 2515.

5.2.3 Semivolatiles (excluding PAHs)

Semivolatiles analyses were performed on background, onsite, and runoff samples collected during this investigation. Laboratory semivolatile analyses were performed using EPA CLP methods.

Background information on concentrations of semivolatiles detected in the environment are discussed for specific compounds. This information is compared with detected semivolatile concentrations in onsite surface water and sediment and runoff surface water samples to identify natural or other sources of semivolatiles.

- Di(2-ethylhexyl)phthalate is a plasticizer whose sources are likely to be associated with waste disposal of plastics. If released to surface water, di(2-ethylhexyl)phthalate will biodegrade fairly rapidly but will also strongly adsorb to sediment. Concentrations detected in U.S. river basins range from 1 $\mu\text{g/L}$ to 80 $\mu\text{g/L}$. Sediment concentrations detected in the U.S. range from 0.069 mg/kg to 0.18 mg/kg (Howard 1989).

- Sources of butylbenzylphthalate, a plasticizer, include the manufacture and distribution of plastics and cellulosic resins. If released to surface water, butylbenzylphthalate will partition to sediment. Median concentrations detected in ambient U.S. surface water were less than 10 $\mu\text{g/L}$. Average concentrations in sediment were detected at concentrations as high as 0.63 ng/g (Howard 1989).
- Sources of 4-nitrophenol are associated with industrialized areas and include vehicular exhaust and impurity in some insecticides. In water and sediment, 4-nitrophenol biodegrades, although adsorption to sediment is low. Ambient water concentrations reported in the U.S. EPA STORET database were less than 10 $\mu\text{g/L}$ with a 2 percent detection in the sediment samples (Howard 1989).
- Phenol is common in industrial areas and other sources including auto exhaust and disinfectants. If released to water, phenol will biodegrade fairly rapidly and will not significantly adsorb to sediment. Concentrations in U.S. surface water average 5 $\mu\text{g/L}$ and ambient water ranged from 1.5 $\mu\text{g/L}$ to greater than 100 $\mu\text{g/L}$. Sediment concentrations in U.S. have been detected at a average of 6.1 mg/kg dry weight up to 608 mg/kg dry weight (ATSDR 1988d; Howard 1989). Concentrations of phenol were detected in a surface water sample collected in the Leach Creek area at 2,200 $\mu\text{g/L}$ and in a sediment sample at 74 $\mu\text{g/kg}$ (Lum and Turney 1985).

5.2.3.1 Background. Semivolatiles analyses were performed on background samples collected during the wet and dry season sampling events. The only semivolatile compounds detected in the background samples collected during the dry season was bis(2-ethylhexyl)phthalate at Location 2500 and during the wet season at Locations 2500 and 2541. No WQC exists for bis(2-ethylhexyl)phthalate.

5.2.3.2 Onsite Surface Water. Semivolatile organic compounds analyses were performed on onsite surface water and sediment samples collected during the transitional, dry, and wet season sampling events. Concentrations of detected semivolatile organic compounds in onsite surface water and sediment samples collected during the transitional season are presented in Appendix SW-D and Table SW-12. Semivolatile organic compounds were not detected in surface water during this season.

Concentrations of semivolatile organic compounds in onsite surface water collected during the dry season are presented in Appendix SW-D and Table SW-12. The only detected semivolatile organic compounds were 4-methylphenol and bis(2-ethylhexyl)phthalate. 4-Methylphenol was detected in only one sample (4 $\mu\text{g/L}$ at Location 2527). Bis(2-ethylhexyl)phthalate was detected in four locations. Detected concentrations ranged from 5 $\mu\text{g/L}$ at Locations 2501 and 2527 to 55 $\mu\text{g/L}$ at Location 2528. Background results from dry season showed that bis(2-ethylhexyl)phthalate was detected at 6 $\mu\text{g/L}$ at Location 2500.

Concentrations of semivolatile organic compounds in onsite surface water collected during the wet season are presented in Appendix SW-D and Table SW-12. Eight semivolatile organic compounds [4-methylphenol, 4-nitrophenol, diethylphthalate, n-nitrosodiphenyl-phenylamine, pentachlorophenol, butylbenzylphthalate, bis(2-ethylhexyl)phthalate, and di-n-octylphthalate] were detected in surface water samples collected during this event. Detected concentrations ranged from 0.5 $\mu\text{g/L}$ for butylbenzylphthalate (Location 2503) to 37 $\mu\text{g/L}$ for bis (2-ethylhexylphthalate) (Location 2516). bis(2-Ethylhexyl)phthalate was detected in two background surface water samples collected during the wet season at concentrations of 0.9 $\mu\text{g/L}$ and 2 $\mu\text{g/L}$.

5.2.3.3 Onsite Sediment. Concentrations of semivolatile organic compounds in onsite sediment samples collected during the transitional season are presented in Appendix SW-D. Four semivolatile organic compounds (phenol, 4-methylphenol, 2-methylnaphthalene, and butylbenzylphthalate) were detected in sediment samples

collected from Reach C during this season. Concentrations ranged from 54 $\mu\text{g/kg}$ (4-methylphenol at Location 2516) to 5,000 $\mu\text{g/kg}$ (4-methylphenol at Location 2506).

Concentrations of semivolatile organic compounds in onsite sediment samples collected during the dry season are presented in Appendix SW-D. Nine semivolatile organic compounds, [phenol, 2-methylnaphthalene, dimethylphthalate, dibenzofuran, carbazole, di-n-butylphthalate, butylbenzylphthalate, bis(2-ethylhexyl)phthalate, and di-n-octyl-phthalate] were detected in sediment samples. Concentrations ranged from 31 $\mu\text{g/kg}$ (dibenzofuran at Location 2511) to 160,000 $\mu\text{g/kg}$ [bis(2-ethylhexyl)phthalate at Location 2502]. Semivolatile organic compounds were detected in samples collected throughout the surface water channel. The most frequently detected semivolatile organic compounds (other than PAHs) were phthalates, particularly bis(2-ethylhexyl)phthalate and butylbenzylphthalate.

Concentrations of semivolatile organic compounds in onsite sediments samples collected during the wet season are presented in Appendix SW-D. Nine semivolatile organic compounds [phenol, 4-methylphenol, 2-methylnaphthalene, dimethylphthalate, dibenzofuran, carbazole, di-n-butylphthalate, butylbenzylphthalate, bis(2-ethylhexyl)phthalate, and di-n-octyl-phthalate] were detected in sediment samples. Concentrations ranged from 26 $\mu\text{g/kg}$ (2-methylnaphthalene at Location 2514) to 120,000 $\mu\text{g/kg}$ [bis(2-ethylhexyl)phthalate at Location 2502]. Semivolatile organic compounds were detected in samples collected throughout the surface water channel, although the most elevated concentrations were associated with samples from Reach A. The most frequently detected semivolatile organic compounds (other than PAHs) were phthalates, particularly bis(2-ethylhexyl)phthalate and butylbenzylphthalate.

5.2.3.4 Runoff. Semivolatiles analyses were performed on runoff surface water samples collected during biweekly and storm events. The only semivolatile compounds (other than PAHs) detected in runoff surface water samples (both

biweekly and storm water runoff at Location 2515) were pentachlorophenol and bis(2-ethylhexyl)phthalate. AFWQC was not exceeded for pentachlorophenol concentrations. No WQC exists for bis(2-ethylhexyl)phthalate.

5.2.3.5 Semivolatile TICs

Tentatively identified semivolatiles organic compounds (semivolatile TICs) were reported by the laboratory during this investigation. A brief discussion of some of the semivolatile TICs is presented herein. A summary of these results is presented in Tables SW-15, SW-16, and SW-17 and database printouts for semivolatile TICs are provided in Section 7.0 of the Data Appendix.

Background. During the dry season sampling event, background semivolatile TICs ranged in concentration from 2 $\mu\text{g/L}$ to 140 $\mu\text{g/L}$. Hexadecanoic acid was detected at the highest concentration at Location 2500. Most of these TICs were unknown with 4-hydroxy-4-methyl-2-pentanone occurring twice.

During the wet season sampling event, background semivolatile TICs ranged in concentrations from 2 $\mu\text{g/L}$ to 6 $\mu\text{g/L}$. An unknown compound was detected at the highest concentration at Location 2500. Most of the TICs were unknown; no known compounds occurring more than once.

Onsite Surface Water. Semivolatile TICs were detected in onsite surface water and sediment samples collected during the three seasonal sampling events and are summarized in Table SW-16.

Semivolatile TICs detected in onsite surface water samples collected during the transitional season ranged from 4 $\mu\text{g/L}$ for several compounds to 600 $\mu\text{g/L}$ for 2-hydroxy methyl propanoic acid at Location 2509. Most TICs were nonchlorinated branched and unbranched alkanes with some alkenes, ketones, and carboxylic acids. Most compounds primarily consisted of greater than 10 to 22 carbon molecules. A few unknown TICs were also detected.

TABLE SW-15**SEMIVOLATILE TICS DETECTED IN
BACKGROUND SURFACE WATER SAMPLES**

Background Location Number	Number of TICs Detected	Range of Concentrations ($\mu\text{g/L}$)
Dry Season Event (August 1991)		
2500	19	2-140
2540	6	2-6
2541	17	2-7
2542	10	2-20
2543	16	2-25
Wet Season Event (January 1992)		
2500	3	2-6
2540	4	2-5
2541	0	--
2542	1	2
2543	1	2

TABLE SW-16

**SEMIVOLATILE TICS DETECTED IN
ONSITE SURFACE WATER AND SEDIMENT SAMPLES**

Reach	Onsite Location Number	Transitional Season Event (April 1991)				Dry Season Event (August 1991)				Wet Season Event (January 1992)			
		Surface Water		Sediment		Surface Water		Sediment		Surface Water		Sediment	
		No. of Detects	Range (µg/L)	No. of Detects	Range (µg/kg)	No. of Detects	Range (µg/L)	No. of Detects	Range (µg/kg)	No. of Detects	Range (µg/L)	No. of Detects	Range (µg/kg)
A	2501	NS ^(a)	--	NS	--	15	2-21	1	1,900	9	2-4	3	194-700
A	2502	NS	--	NS	--	13	2-100	9	11,000-39,000	9	2-8	1	24,000
A	2503	NS	--	NS	--	20	2-22	12	6,100-24,000	13	2-9	5	8,800-24,000
A	2527	NS	--	NS	--	20	2-42	20	9,500-170,000	4	2-4	10	3,400-920,000
A	2528	NS	--	NS	--	6	2-17	1	7,200	14	2-8	3	3,000-4,200
A	2529	NS	--	NS	--	6	2-5	0	--	17	2-5	2	1,660-2,000
A	2530	NS	--	NS	--	14	2-28	1	2,200	15	2-8	3	1,580-10,000
B	2504	NS	--	NS	--	NS	--	3	2,700-22,000	NS	--	6	280-2,800
B	2506	7/3 ^(b)	4-11	19	300-2,770	NS	--	13/3 ^(b)	670-15,000	2/2 ^(b)	2-6	12	520-5,200
B	2507	NS	--	NS	--	NS	--	7	950-9,800	2	2-4	20	960-54,000
B	2518	NS	--	NS	--	NS	--	2	13,000-20,000	3	2-8	2	4,400-9,600
B	2519	NS	--	NS	--	NS	--	4	13,000-61,000	1	5	2	1,560-10,400
B	2520	NS	--	NS	--	NS	--	3	20,000-35,000	1	2	6	800-7,800
B	2521	NS	--	NS	--	NS	--	2	5,700-13,000	3	2-16	15	540-8,200
B	2522	NS	--	NS	--	NS	--	1	3,500	NS	--	6	1,120-9,000
B	2523	NS	--	NS	--	NS	--	0	--	NS	--	2	3,000-6,600
B	2524	NS	--	NS	--	NS	--	0	--	NS	--	1	3,400
B	2525	NS	--	NS	--	NS	--	0	--	NS	--	3	1,980-3,600
B	2526	NS	--	NS	--	NS	--	1	11,000	NS	--	2	3,800-10,000

TABLE SW-16

**SEMIVOLATILE TICS DETECTED IN
ONSITE SURFACE WATER AND SEDIMENT SAMPLES**

Reach	Onsite Location Number	Transitional Season Event (April 1991)				Dry Season Event (August 1991)				Wet Season Event (January 1992)			
		Surface Water		Sediment		Surface Water		Sediment		Surface Water		Sediment	
		No. of Detects	Range ($\mu\text{g/L}$)	No. of Detects	Range ($\mu\text{g/kg}$)	No. of Detects	Range ($\mu\text{g/L}$)	No. of Detects	Range ($\mu\text{g/kg}$)	No. of Detects	Range ($\mu\text{g/L}$)	No. of Detects	Range ($\mu\text{g/kg}$)
C	2505	NS	--	NS	--	NS	--	9	700-9,500	6	2-6	NS	--
C	2508	NS	--	NS	--	8	2-4	20	490-13,000	1	4	11	580-14,200
C	2509	2/7 ^(b)	4-13	18	67-600	NS	--	6/18 ^(b)	340-9,300	1/0 ^(b)	6	16/19 ^(b)	106-17,400
C	2510	NS	--	NS	--	7	2-6	4	1,200-2,000	1	5	20	3,200-40,000
C	2511	3/3 ^(b)	4-48	19	133-3,670	NS	--	20/20 ^(b)	130-5,500	3/6 ^(b)	2-8	16/19 ^(b)	160-6,800
C	2512	NS	--	NS	--	NS	--	20	180-6,400	3	6-20	20	440-10,800
D	2513	NS	--	NS	--	NS	--	3	560-1,100	NS	--	9	90-960
D	2514	NS	--	NS	--	NS	--	3	420-1,900	NS	--	8	104-1,480
D	2515	NS	--	NS	--	NS	--	1	810	NS	--	4	240-2,600
NA ^(c)	2516	4/4 ^(b)	4-11	18/18 ^(b)	233-1,700	NS	--	13/16 ^(b)	68-990	3/2 ^(b)	2-4	18/18 ^(b)	108-2,400

(a) NS = No sample collected.

(b) Two discrete samples were collected from Locations 2506, 2509, 2511, and 2516.

(c) NA = Not applicable (Location 2516 is outside surface water channel).

TABLE SW-17

SEMIVOLATILE TICS DETECTED IN SURFACE WATER RUNOFF SAMPLES

Sample Location 2515	Number of TICs Detected	Range of Concentrations (μg/L)
Monthly Events		
4/4/91	6	4-30
11/27/91	2	2-4
2/3/92	1	5
3/2/92	2	2-4
Storm Event		
1/28/92	1	4

Semivolatile TICs detected in onsite surface water samples collected during the dry season ranged from 2 $\mu\text{g/L}$ for several compounds to 100 $\mu\text{g/L}$ for hexadecanoic acid at Location 2502. Most TICs were nonchlorinated branched and unbranched alkanes and carboxylic acids with a few alcohols and ketones. The length of the carbon chains primarily ranged from greater than 10 to 44. Several unknown TICs were also detected.

Semivolatile TICs detected in onsite surface water samples collected during the wet season ranged from 2 $\mu\text{g/L}$ for many compounds to 20 $\mu\text{g/L}$ for 2-[1-oxo]octadecanoic acid at Location 2512. TICs were primarily nonchlorinated branched and unbranched alkanes, alcohols, and carboxylic acids with a few ketones. The length of the carbon chains primarily ranged from greater than 10 to 35 carbon atoms. Several unknown TICs were also detected.

Onsite Sediment. Concentrations of semivolatile TICs detected in onsite sediment samples collected during the transitional season ranged from 133 $\mu\text{g/kg}$ for an unknown compound at Location 2511 to 3,670 $\mu\text{g/kg}$ for 2-pentanol at Location 2511. Most TICs were nonchlorinated branched and unbranched alkanes, alkenes, alcohols, aldehydes, and carboxylic acids. Most of these compounds consisted of greater than 10 to as many as 35 carbon atoms. A few unknown TICs were also detected.

Concentrations of semivolatile TICs detected in onsite sediment samples collected during the dry season ranged from 68 $\mu\text{g/kg}$ for an unknown compound at Location 2516 to 1,700,000 $\mu\text{g/kg}$ for methyl 11-octadecanoic acid at Location 2527. TICs were primarily nonchlorinated branched and unbranched alkanes and carboxylic acids, with a few alkenes, aldehydes, and alcohols, and ketones. The length of the carbon chains primarily ranged from greater than 10 to 34 carbon atoms. Several unknown TICs were also detected.

Concentrations of semivolatile TICs detected in onsite sediment samples collected during the wet season ranged from 90 $\mu\text{g/kg}$ for 9-octyl-heptadecane at Location 2513 to 920,000 $\mu\text{g/kg}$ for hexadecanoic acid at Location 2527. TICs were primarily nonchlorinated branched and unbranched alkanes and carboxylic acids with a few alkenes, alcohols, aldehydes, and ketones. The number of carbon atoms ranged from greater than 10 to as many as 35. Several unknown TICs were also detected.

Runoff. Several semivolatile TICs were detected in runoff biweekly and stormwater samples collected at Location 2515. A summary of these results is presented in Table SW-17. Concentrations of semivolatile TICs detected in runoff biweekly and stormwater samples ranged from 2 $\mu\text{g/L}$ to 30 $\mu\text{g/L}$. Beta-pinene was detected at the highest concentration (30 $\mu\text{g/L}$) in a biweekly sample. In general, unknown TICs were detected in both biweekly and storm water samples.

5.2.4 PCBs/Pesticides

PCB/pesticide analyses were performed on surface water and sediment samples using EPA CLP methods.

Background information on concentrations of PCBs/pesticides detected in the environment are discussed for specific compounds. This information is compared with PCBs/pesticides concentrations detected in onsite surface water and sediment and runoff surface water samples to identify natural or other sources of PCBs/pesticides.

- Endosulfan, an insecticide, generally degrades to several isomers in the environment. Concentrations of these isomers are detected in surface water at less than 1 $\mu\text{g/L}$. Sediment concentrations were detected in the low ppm usually less than 5 $\mu\text{g/kg}$ (Howard 1991).

- Endrin is an insecticide that is not presently used to a great extent. Endrin is very persistent in the environment. If released to water, endrin will extensively sorb to sediment. Median concentrations detected in U.S. ambient water and sediment were 0.001 $\mu\text{g/L}$ and 0.01 $\mu\text{g/kg}$, respectively (Howard 1991).
- Aldrin, an insecticide, is no longer produced or used in the U.S. Aldrin adsorbs to sediment significantly and degrades slowly. U.S. surface water and sediment were detected at a median concentrations of 0.001 $\mu\text{g/L}$ and 0.1 $\mu\text{g/kg}$ dry weight, respectively (Howard 1991).
- Methoxychlor is an insecticide. If released to water, methoxychlor will adsorb to suspended solids and sediment. Water and sediment concentrations are generally detected in trace amounts (Howard 1991).
- The major current source of PCBs is recycling of PCBs previously introduced into the environment. Aroclor 1254 and 1260 are resistant to biodegradation, degrading very slowly in the environment. Current releases of PCBs appear to be associated with landfills containing transformers, capacitors and other disposed contaminated materials. In water, PCBs tend to adsorb to sediment and suspended matter. Sediment concentrations were detected up to 33.3 mg/kg (ATSDR 1987I).

PCBs and pesticides were not detected in surface water samples collected during any of the sampling events and not detected in sediment samples collected during the transitional season.

5.2.4.1 Onsite Sediment. Concentrations of PCBs and pesticides in onsite sediment samples collected during the dry season are presented in Appendix SW-D. Twelve compounds were detected in dry season sediment samples: alpha-BHC, aldrin, 4,4-DDE, endrin, endosulfan II, 4,4-DDD, endosulfan sulfate, 4,4-DDT, methoxychlor, endrin ketone, Aroclor-1254, and Aroclor-1260. Concentrations

ranged from 20 $\mu\text{g/kg}$ (aldrin at Location 2527) to 2,700 $\mu\text{g/kg}$ (Aroclor-1260 at Location 2506) and were associated with samples collected in Reaches A and B.

Concentrations of PCBs and pesticides in onsite sediment samples collected during the wet season are presented in Appendix SW-D. Two PCBs compounds, Aroclor-1254 and Aroclor-1260 were detected in wet season sediment samples. Aroclor-1254 was detected in only one sample (190 $\mu\text{g/kg}$ at Location 2514).

Concentrations of Aroclor-1260, which was detected at estimated concentrations in 16 samples, ranged from 130 $\mu\text{g/kg}$ at Location 2513 to 4,000 $\mu\text{g/kg}$ at Location 2519. These concentrations were detected in samples collected primarily from Reach B. A few concentrations were detected in samples collected from Reach A and the Aroclor-1254 was detected in a sample collected from Reach D.

5.2.5 Summary of Organic Results

PAHs detected at two background locations in the dry season were phenanthracene, fluoranthene, pyrene, chrysene, fluorene, benzo(a)anthracene, and benzo(b)fluoranthene. PAHs detected at two background locations in the wet season were phenanthrene, fluoranthene, and pyrene. PAHs were detected more frequently and at higher concentrations at the dry season background locations than at the wet season background locations. Two carcinogenic PAHs were detected in the dry season samples [chrysene and benzo(a)anthracene]. No carcinogenic PAHs were detected in the wet season samples.

Only two VOCs, acetone and chloroform, were detected in the samples collected in the dry season at the background locations. Only one non-PAH semivolatile compound, bis(2-ethylhexyl)phthalate, was detected in surface water samples collected during the dry and wet seasons at the background locations. No PCB/pesticides were detected in the background surface water samples.

The most frequently detected PAHs in the surface water runoff samples were fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-c,d)pyrene, and benzo(g,h,i)perylene. Six of the seven carcinogenic PAHs were detected in the monthly runoff samples and all seven were detected in the stormwater runoff samples.

In the monthly runoff samples, most PAHs were detected at concentrations of less than 1 $\mu\text{g/L}$. Phenanthrene, fluoranthene, pyrene, and chrysene were detected at concentrations ranging from 1 $\mu\text{g/L}$ to 3 $\mu\text{g/L}$. These concentrations were similar at both runoff sampling locations.

In the stormwater runoff samples, PAHs were detected more frequently and at higher concentrations than PAHs detected in the monthly runoff samples. PAHs were also detected more frequently and at higher concentrations at Location 2500 than at Location 2501.

Low concentrations of PAHs and some VOCs and semivolatile organic compounds were detected in onsite surface water samples collected during the three seasonal events. PCBs and pesticides were not detected in any onsite surface water samples collected during the three seasonal events. PAHs were the most commonly detected compounds. Analytical results from runoff surface water samples collected showed all PAHs were detected up to 5.4 $\mu\text{g/L}$ (fluoranthene at Location 2500).

Anthracene was the only PAH detected in surface water samples collected during the transitional season. During the dry season, PAHs were detected in all surface water samples (except samples collected from Locations 2508 and 2510). The most elevated PAH concentration was for fluoranthene (8.2 $\mu\text{g/L}$ at Location 2528). Concentrations of total PAHs and carcinogenic PAHs ranged up to 39 $\mu\text{g/L}$ and 14 $\mu\text{g/L}$, respectively, at Location 2528.

During the wet season, PAHs were detected in 12 of 24 onsite surface water samples, primarily collected from Reach A. The maximum concentration for an individual PAH compound was 7.7 $\mu\text{g/L}$ for fluoranthene at Location 2502. Concentrations of total PAHs and carcinogenic PAHs ranged up to 27 $\mu\text{g/L}$ and 9.8 $\mu\text{g/L}$, respectively, at Location 2502.

VOCs were not detected in onsite surface water samples collected during the transitional season. During the dry season, only chloroform and toluene were detected in onsite samples in concentrations that ranged up to 7 $\mu\text{g/L}$ (toluene at Location 2502). During the wet season, methylene chloride and chloroform were detected in a few locations.

Semivolatile organic compounds were not detected in onsite surface water samples during the transitional season. During the dry season, only 4-methylphenol and bis(2-ethylhexyl)phthalate were detected in concentrations that ranged up to 55 $\mu\text{g/L}$ [bis(2-ethylhexyl)phthalate at Location 2528]. During the wet season, eight semivolatile organic compounds were detected. Concentrations ranged up to 37 $\mu\text{g/L}$ for bis(2-ethylhexyl)phthalate at Location 2516.

Organics were detected in most of the onsite sediment samples collected during the three seasonal events. Concentrations of individual PAH compounds ranged up to 130 mg/kg for fluoranthene in a sample collected from Location 2503 during the wet season. Total PAHs ranged up to 560 mg/kg at Location 2503 in a wet season sample. Carcinogenic PAHs ranged up to 200 mg/kg at Location 2503 in the same season. Total and carcinogenic PAHs, when presented on a dry weight basis, were the most elevated in the northern section of Reach A in both the dry and wet seasons. PAH concentrations decreased rapidly in the southern section of Reach A and the northern section of Reach B. In the southern section of Reach B and all of Reaches C and D, concentrations remained relatively low.

VOCs were detected in onsite sediment samples collected during all three seasonal events. Samples collected during the dry season showed the greatest number (9)

of individual VOCs and the most elevated concentration (6,400 $\mu\text{g}/\text{kg}$ for toluene at Location 2527).

Semivolatile organic compounds were detected in onsite sediment samples collected during all three sampling events. In the transitional season, four compounds were detected (all collected from Reach C). During the dry season, nine semivolatile organic compounds were detected in samples collected throughout the surface water channel at concentrations that ranged up to 160,000 $\mu\text{g}/\text{kg}$ for bis(2-ethylhexyl)phthalate at Location 2502. During the wet season, nine semivolatile organics were also detected in samples collected throughout the channel at concentrations that ranged up to 120,000 $\mu\text{g}/\text{kg}$ for bis(2-ethylhexyl)phthalate at Location 2502.

PCBs and pesticides were detected in onsite sediment samples collected during the dry and wet seasons, but not in samples collected during the transitional season. Detected concentrations were primarily associated with samples collected from Reaches A and B. The most elevated concentration was 4,000 $\mu\text{g}/\text{kg}$ for PCBs (Aroclor 1260) in a sample collected from Location 2519 during the wet season.

Phenanthrene, fluoranthene, and pyrene were detected at concentrations of less than 0.2 $\mu\text{g}/\text{L}$ in the stormwater runoff samples. In addition, anthracene was detected in one biweekly surface water runoff sample. The PAHs concentrations detected in the runoff stormwater sample were consistent with the concentrations detected in runoff samples. The only semivolatile compounds detected in the runoff surface water samples (both biweekly and stormwater runoff) were pentachlorophenol (PCP) and bis(2-ethylhexyl)phthalate. The AFWQC was not exceeded for PCP. No WQC has been proposed for bis(2-ethylhexyl)phthalate).

5.3 FECAL BACTERIA

This section contains a discussion of the fecal bacteria (coliform and streptococci) results. Tables SW-18 through SW-21 provide comparisons of the fecal coliform and fecal streptococci bacteria concentrations detected in surface water collected from background locations to WQC for fecal bacteria.

The WQC for fecal coliform for class B (good surface water quality) are the geometric mean value of the samples collected from a location not to exceed 200 organisms/100 mL and the maximum value of 10 percent of the samples collected from a location not to exceed 400 organisms/100 mL.

5.3.1 Background

Fecal coliform bacteria detected in background samples collected during the dry season ranged from 60 most probable number (MPN)/100 mL to 36,000 MPN/100 mL (see Table SW-18). Fecal streptococci bacteria detected in background samples collected during the dry season ranged from 18 MPN/100 mL to 15,000 MPN/100 mL. Fecal coliform bacteria detected in background samples collected during the wet season ranged from undetected to 3,000 MPN/100 mL. Fecal streptococci bacteria detected in background samples collected during the wet season ranged from undetected to 31,000 MPN/100 mL.

Approximately 50 percent of the background samples (dry and wet seasons) exceeded the WQC. At three background locations, fecal bacteria concentrations detected in samples collected during the dry season were higher than those detected during the wet season. The fecal streptococci bacteria concentration detected during the wet season at background Location 2541 exceeded the dry season concentration by approximately a factor of two.

TABLE SW-18

FECAL BACTERIA DETECTED IN BACKGROUND SURFACE WATER SAMPLES^(a,b)

Background Location Number	Fecal Coliform (MPN/100 mL)	Fecal Streptococcus (MPN/100 mL)
Dry Season Event (August 1991)		
2500	36,000	13,000
2540	60.0	18.0
2541	33,000	15,000
2542	400	8,100
2543	140	50.0
Wet Season Event (January 1992)		
2500	3,000	8,200
2540	U 2.0	U 2.0
2541	3,000	31,000
2542	88.0	92.0
2543	16.0	12.0

(a) Draft Water Quality Standards for Surface Waters of the State of Washington (WAC 173-201, 1988).

(b) Water quality criteria Class B (good): geometric mean value not to exceed 200 organisms/100 mL; maximum value of 10% of all samples not to exceed 400 organisms/100 m/L.

TABLE SW-19

FECAL BACTERIA DETECTED IN SURFACE WATER RUNON SAMPLES^(a,b)

Sample Location 2500	Fecal Coliform (MPN/100 mL)	Fecal Streptococcus (MPN/100 mL)	Sample Location 2501	Fecal Coliform (MPN/100 mL)	Fecal Streptococcus (MPN/100 mL)
Monthly Events			Monthly Events		
4/4/91	1,400	1,500	4/4/91	1,700	4,100
4/30/91	30.0	6.0	4/30/91	3,300	240
5/29/91	4.0	550	5/29/91	200	20.0
6/25/91	12.0	56.0	6/25/91	43,000	58,000
7/91 (no flow)	NS ^(c)	NS	7/91 (no flow)	NS	NS
8/22/91	130,000	920,000	8/22/91 (no flow)	NS	NS
9/91 (no flow)	NS	NS	9/91 (no flow)	NS	NS
10/16/91	200	43,000	10/16/91	24,000	60,000
11/14/91	9,000	46.0	11/14/91	11,000	4,400
12/12/91	900	8,300	12/12/91	44,000	73,000
1/17/92	120	80.0	1/17/92	42,000	280
2/6/92	20.0	2,700	2/6/92	1,400	720
3/2/92	60.0	3,500	3/2/92	1,900	800
Storm Events			Storm Events		
4/2/91	480	2,400	4/2/91	4,700	6,800
5/24/91	1,700	2,100	5/24/91	10,000	19,000
7/24/91	2,000	4,500	7/24/91	7,000	6,600
8/9/91	10,000	45,000	8/9/91	80,000	39,000
10/22/91	4,400	31,000	10/22/91	20,000	51,000
11/11/91 ^(d)	--	--	11/11/91 ^(d)	--	--
12/18/91	1,700	5,800	12/18/91	42,000	51,000
1/23/92	1,600	680	1/23/92	18,000	8,800
2/13/92	3,900	6,300	2/13/92	190,000	82,000
2/18/92	23,000	23,000	2/18/92	80,000	35,000
3/17/92	2,600	2,500	3/17/92	180,000	50,000

(a) Draft Water Quality Standards for Surface Waters of the State of Washington (WAC 173-201, 1988).

(b) Water quality criteria Class B (good): geometric mean value not to exceed 200 organisms/100 mL; maximum value of 10% of all samples not to exceed 400 organisms/100 mL.

(c) NS - No sample collected.

(d) Stormwater sample collected for fecal bacteria analysis was discarded because laboratory was not open (i.e., holding time expired).

TABLE SW-20

FECAL BACTERIA DETECTED IN SEASONAL ONSITE SURFACE WATER SAMPLES^(a,b)

Seasonal Sampling Event	Fecal Coliform (MPN/100 mL)	Fecal Streptococcus (MPN/100 mL)
Transitional Season (April 1991)		
Minimum	U 1.0	U 1.0
Maximum	330.0	22.0
Dry Season (August 1991)		
Minimum	2,800	180
Maximum	270,000	240,000
Wet Season (January 1992)		
Minimum	U 2.0	U 2.0
Maximum	30,000	37,000

(a) Draft Water Quality Standards for Surface Waters of the State of Washington (WAC 173-201, 1988).

(b) Water quality criteria Class B (good): geometric mean value not to exceed 200 organisms/100 mL; maximum value of 10% of all samples not to exceed 400 organisms/100 mL.

TABLE SW-21

FECAL BACTERIA DETECTED IN SURFACE WATER RUNOFF SAMPLES^(a,b)

Location 2515	Fecal Coliform (MPN/100 mL)	Fecal Streptococcus (MPN/100 mL)
Biweekly Events^(c)		
4/4/91	160.0	160.0
2/3/92	52.0	44.0
2/19/92	600.0	520.0
Storm Event^(d)		
1/28/92	1,500	2,300

- (a) Draft Water Quality Standards for Surface Waters of the State of Washington (WAC 173-201, 1988).
- (b) Water quality criteria Class B (good): geometric mean value not to exceed 200 organisms/100 mL; maximum value of 10% of all samples not to exceed 400 organisms/100 mL.
- (c) Surface water runoff samples were scheduled to be collected biweekly from downgradient location 2515. However, because surface water flow was seldom observed at this location, a total of three samples was collected.
- (d) Surface water runoff samples were scheduled to be collected from downgradient location 2515 during 12 storm events. However, because surface water flow was seldom observed at this location, only one stormwater runoff sample was collected.

5.3.2 Runon

Fecal coliform and fecal streptococci bacteria analyses were performed on samples collected during monthly and storm events from Locations 2500 and 2501 (the two upgradient runon locations). Monthly runon concentrations ranged from 4 MPN/100 mL to 130,000 MPN/100 mL for the fecal coliform and from 6 MPN/100 mL to 920,000 MPN/100 mL for the fecal streptococci (see Table SW-19). Stormwater runon concentrations ranged from 480 MPN/100 mL to 190,000 MPN/100 mL for fecal coliform and from 680 MPN/100 mL for to 82,000 MPN/100 mL for fecal streptococci.

At Location 2500, one-third of the monthly runon fecal coliform bacteria concentrations were above the WQC of 400 organisms/100 mL. The monthly runon sample at Location 2501 and the stormwater runon samples at both locations were consistently detected at concentrations higher than the WQC.

Fecal coliform concentrations for monthly and stormwater runon samples are similar at Location 2501 (see Appendix SW-B). The fecal streptococci concentrations at Location 2501 were generally higher than the concentrations detected in the monthly runon samples. Two monthly runon concentrations (June and October 1991) exceeded the stormwater fecal streptococci concentrations at Location 2501. However, the fecal coliform and streptococci concentrations at Location 2500 were higher in the stormwater runon samples than the monthly runon samples. In August 1991, a fecal streptococci concentration in a monthly runon sample collected at Location 2500 exceeded all sample concentrations. Bacteria concentrations were higher in samples collected at Location 2501 than at Location 2500. Concentrations of bacteria in samples collected at Location 2500 increased during the months of July to October. No seasonal variation was present at Location 2501.

The fecal coliform and streptococci bacteria detected in samples collected at Location 2500 were generally detected at the same concentrations detected in the

background surface water concentrations. One-third of the fecal coliform and streptococci concentrations detected in samples collected at Location 2501 were higher than the concentrations detected in the background surface water samples.

5.3.3 Onsite Surface Water

Fecal coliform and streptococci bacteria analyses were performed on samples collected during the transitional, dry, and wet seasons from onsite surface water locations.

The onsite surface water concentrations ranged from 1.0 MPN/100 mL to 270,000 MPN/100 mL for the fecal coliform bacteria and from 1.0 MPN/100 mL to 240,000 MPN/100 mL for the streptococci bacteria (see Table SW-20). The higher concentrations of fecal coliform bacteria and streptococci bacteria were detected in samples collected during the dry season. In comparison with the WQC, the dry season onsite fecal coliform concentrations exceeded 200 organisms/100 mL and exceeded the 400 organisms/100 mL. One-third of the wet season onsite fecal coliform concentrations exceeded WQC. Concentrations of fecal bacteria detected in onsite samples were within the range of those detected in background surface water samples.

5.3.4 Runoff

Coliform and streptococci bacteria analyses were performed on surface water runoff samples collected at Location 2515. The biweekly surface water runoff concentrations ranged from 52 MPN/100 mL to 600 MPN/100 mL for the fecal coliform bacteria and from 44 MPN/100 mL to 520 MPN/100 mL for the fecal streptococci bacteria (see Table SW-21). The higher concentrations of fecal coliform bacteria and fecal streptococci bacteria were detected in samples collected during the stormwater event. In comparison with the WQC, the surface water

runoff geometric mean concentrations of fecal coliform bacteria (580 MPN/100 mL) exceed 200 organisms/100 mL and half (50 percent) of the fecal coliform bacteria concentrations exceeded the 400 organisms/100 mL. Concentrations of fecal bacteria detected in runoff samples were within the range of those detected runoff surface water samples.

5.4 FIELD MEASUREMENTS AND OBSERVATIONS

Field measurements recorded during the various sampling events of this investigation included field pH and temperature. These field measurements are summarized in Tables SW-22 through SW-25.

Field observations were recorded on Surface Water Sampling Forms during sample collection. The following observations were noted on the sampling forms:

- Sampling location description
- Field measurements (pH, temperature, turbidity, flow)
- Laboratory analyses requested
- Comments.

Field pH measurements of background surface water were lower in the dry season than the pH measurements of the wet season background samples. Field pH conditions for surface water runoff (dry and wet seasons) varied between 4.5 and 7.4. Field pH conditions for onsite surface water were similar for all three seasonal events, varying between 5.7 and 7.9. Field pH conditions for surface water runoff varied between 5.6 and 7.2. All temperature readings (i.e., for background, runoff, onsite, and runoff samples) varied accordingly with the seasonal temperature differences (i.e., higher in dry season and lower in wet season).

TABLE SW-22

**SUMMARY OF pH AND TEMPERATURE OF SURFACE WATER
DURING BACKGROUND SEASONAL SAMPLING EVENTS**

Background Location Number	Dry Season Event (August 1991)		Wet Season Event (January 1992)	
	pH	Temperature (°C)	pH	Temperature (°C)
2500	6.0	20.5	6.7	5.0
2540	6.2	24.1	6.7	2.4
2541	6.7	17.0	6.9	4.5
2542	6.5	17.1	7.1	3.4
2543	6.2	18.3	7.2	2.3

TABLE SW-23

**SUMMARY OF pH AND TEMPERATURE OF SURFACE WATER
DURING SAMPLING EVENTS AT RUNON LOCATIONS 2500 AND 2501**

Runon Location Number 2500	pH	Temperature (°C)	Runon Location Number 2501	pH	Temperature (°C)
Monthly Events			Monthly Events		
4/4/91	4.5	10.1	4/4/91	7.4	9.8
4/30/91	7.2	13.5	4/30/91	6.9	12.8
5/29/91	6.0	14.2	5/29/91	5.6	12.7
6/25/91	6.0	15.0	6/25/91	5.9	13.6
7/91 (no flow)	--	--	7/91 (no flow)	--	--
8/22/91	6.2	23.4	8/22/91 (no flow)	--	--
9/91 (no flow)	--	--	9/91 (no flow)	--	--
10/16/91	5.7	15.5	10/16/91	5.9	12.0
11/14/91	5.7	14.0	11/14/91	6.3	12.0
12/12/91	5.6	10.1	12/12/91	5.4	8.4
1/17/92	5.6	10.1	1/17/92	6.5	11.9
2/6/92	5.0	not taken	2/6/92	4.8	not taken
3/2/92	5.7	12.8	3/2/92	7.0	10.5
Storm Events			Storm Events		
4/2/91	5.0	not taken	4/2/91	5.0	not taken
5/24/91	6.3	12.4	5/24/91	6.5	12.5
7/24/91	5.8	20.5	7/24/91	5.8	20.0
8/9/91	6.1	19.5	8/9/91	6.8	18.5
10/22/91	6.2	11.2	10/22/91	7.0	11.0
11/11/91	6.0	11.9	11/11/91	5.3	11.6
12/18/91	6.2	5.5	12/18/91	5.3	5.0
1/23/92	6.4	9.5	1/23/92	6.4	9.1
2/13/92	6.3	13.5	2/13/92	6.4	8.0
2/18/92	4.7	6.5	2/18/92	not taken	7.0

TABLE SW-24

**SUMMARY OF pH AND TEMPERATURE OF SURFACE WATER
DURING ONSITE SEASONAL SAMPLING EVENTS**

Onsite Location Number	Transitional Season Event (April 1991)		Dry Season Event (August 1991)		Wet Season Event (January 1992)	
	pH	Temperature (°C)	pH	Temperature (°C)	pH	Temperature (°C)
2501			6.8	22.0	6.2	13.8
2502			6.4	27.5	6.8	8.0
2503			6.3	17.0	6.5	9.0
2505					6.8	7.0
2506	7.0 ^(a)	10.2 ^(a)			6.4 ^(a)	7.0 ^(a)
2507					6.3	6.0
2508			6.6	17.2	5.7	6.5
2509	7.9 ^(a)	14.6 ^(a)			6.9 ^(a)	6.0 ^(a)
2510			6.9	17.8	6.8	7.0
2511	7.2 ^(a)	12.0 ^(a)			6.9 ^(a)	5.5 ^(a)
2512					6.0	6.0
2516	7.1 ^(a)	12.2 ^(a)			6.8 ^(a)	6.9 ^(a)
2518					6.5	2.0
2519					6.6	2.0
2520					6.6	3.0
2521					6.5	2.0
2527			6.5	18.3	6.5	2.0
2528			6.6	17.6	6.1	13.5
2529			6.1	17.8	6.0	13.7
2530			9.5	23.3	6.2	13.6

(a) Average value for two samples collected at one location.

TABLE SW-25

**SUMMARY OF pH AND TEMPERATURE OF SURFACE WATER
DURING SAMPLING EVENTS AT RUNOFF LOCATION 2515**

Runon Location Number 2515	pH	Temperature (°C)
Biweekly Events		
4/4/91	6.2	9.0
11/27/91	6.5	8.0
2/3/92	7.2	28.0
2/19/92	5.6	not taken
Storm Event		
1/28/92	6.2	8.9

5.5 RUNON ANNUAL LOADING RESULTS

This section presents a summary of estimated runon annual loadings to STF. The method for estimating the loadings is presented in Section 3.7.1. The runon annual mass loadings to the site are shown in Table SW-26.

The runon annual mass loadings represent the runon contributions to the STF site from Locations 2500 and 2501 only. Other sources of mass loadings to the surface water channel may exist (i.e., overland runoff), but were not observed during this investigation.

The annual runon mass loadings are based on the investigation period of 1 year (April 1991 to April 1992). The yearly volume of surface water from Locations 2500 and 2501 to the STF site (based on daily precipitation data from McChord AFB) was approximately 100 million gallons.

5.6 RUNOFF MASS LOADING RESULTS

The estimated loadings for the biweekly and stormwater runoff are shown in Table SW-27. The total surface water runoff volume for the four observed offsite flows was 14.6 million gallons. The surface water runoff volume recorded by the flow meter was 23 million gallons.

Other offsite flows may have occurred that were not observed during the weekly field investigations. The recorded flow data and the rainfall data are presented in Figure SW-48. A majority of the recorded flow hydrographs were characteristic of backflow that was observed at the monitoring location from the 56th Street storm drain system. Additional offsite stormwater runoff in the immediate area of the monitoring location (e.g., Madison Street, St. Vincent DePaul, and other local businesses) could have contributed to the total recorded runoff volume.

TABLE SW-26

MASS ANNUAL LOADINGS FOR SURFACE WATER RUNON^(a)

Analyte	Location 2500		Location 2501		Total Runon Loading to STF (lb)
	Monthly (Base) Loading (lb)	Total (Base + Storm) Loading (lb)	Monthly (Base) Loading (lb)	Total (Base + Storm) Loading (lb)	
Aluminum	560	696	1,171	1,347	2,043
Arsenic	4	4	0.4	0.5	4.5
Barium	10	11	10	11	22
Boron	17	17	7	7	24
Chromium	3	3	2	2	5
Cobalt	162	162	0.9	1	163
Copper	9	10	2	2	12
Iron	568	704	1,069	1,208	1,912
Lead	8	11	2	2	13
Magnesium	5,774	5,775	667	705	6,580
Manganese	27	29	34	36	65
Mercury	0	0	0	0	0
Nickel	5	5	3	3	8
Potassium	4,279	4,279	367	395	4,674
Sodium	51,756	53,067	1,112	1,134	54,201
Vanadium	3	3	2	2	5
Zinc	68	78	9	10	88

(a) Annual loading period of 312 days.

TABLE SW-27

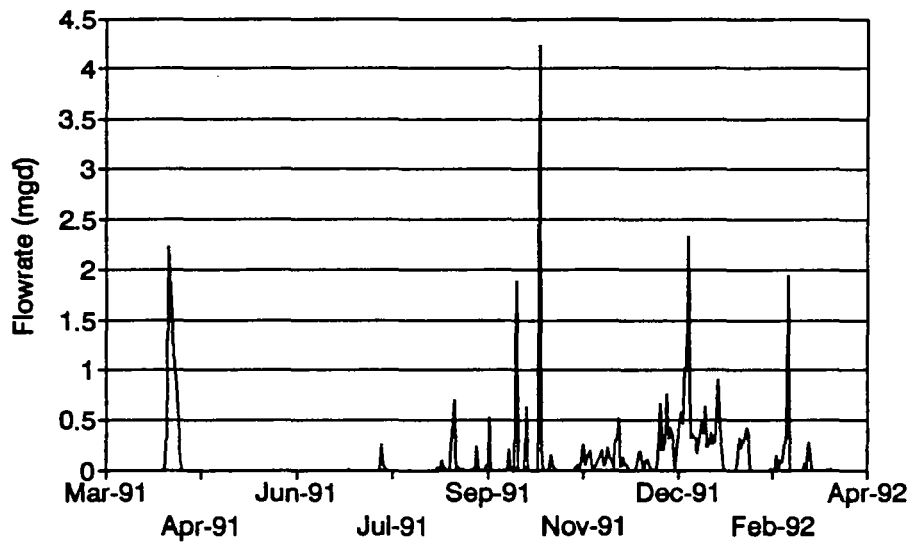
MASS LOADINGS OF SURFACE WATER RUNOFF FROM THE STF SITE

Inorganic	Starting Date of Runoff Event						Total of Runoff Events (lb)
	4/2/91 ^(a)	11/11/91 ^(b)	11/25/91 ^(a)	12/06/91 ^(b)	1/27/92 ^(a)	2/18/92 ^(a)	
	Loadings (lb)						
Aluminum	286.86	1.58	3.09	4.88	41.51	11.2	349.13
Arsenic	0.28	0	0.01	0.01	0.05	0.01	0.35
Barium	2.22	0.02	0.06	0.06	0.65	0.16	3.17
Boron	0.79	0.01	0.15	0.04	0.37	0.04	1.40
Chromium (Total)	0.57	0	0.01	0.01	0.13	0.04	0.76
Cobalt	0.24	0	0.01	0.01	0.06	0.02	0.33
Copper	0.17	0.01	0.03	0.02	0.22	0.05	0.49
Iron	185.33	1.35	3.82	4.16	42.33	10.69	247.68
Lead	0.33	0.01	0.03	0.02	0.09	0.10	0.58
Magnesium	87.35	1.65	6.46	5.10	66.38	19.27	186.20
Manganese	3.73	0.03	0.10	0.09	1.06	0.21	5.23
Mercury	0	0	0	0	0	0	0
Nickel	0.48	0.01	0.03	0.02	0.34	0.04	0.91
Potassium	80.24	1.77	8.63	5.45	75.95	16.95	188.08
Sodium	148.40	10.99	53.97	33.85	529.08	112.98	889.27
Vanadium	0.12	0	0.01	0.01	0.09	0.04	0.26
Zinc	1.59	0.04	0.15	0.11	1.57	0.34	3.79

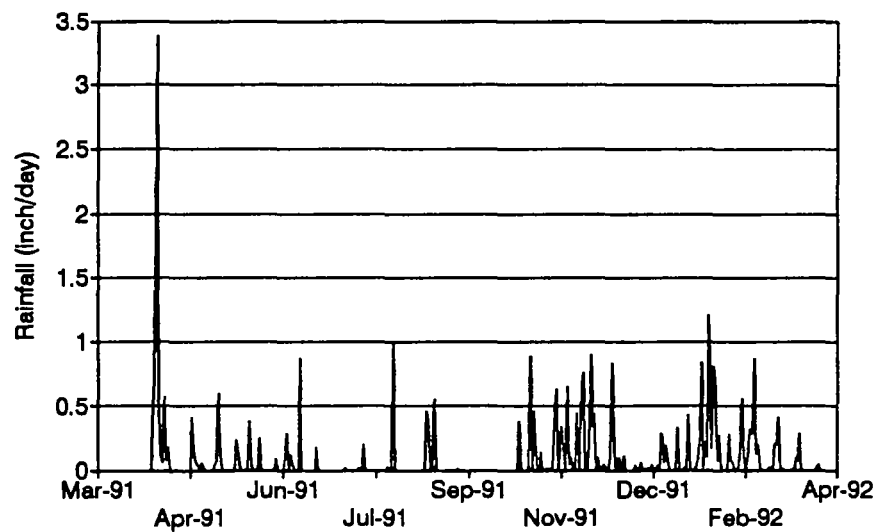
(a) Runoff surface water was observed flowing offsite during this event and a sample was collected for this event.

(b) Runoff surface water flow was not observed. The mass loading is based on an average of the five biweekly/ stormwater runoff samples collected during this investigation.

STF-RUNOFF FLOWRATE



STF-RUNOFF RAINFALL



Kennedy/Jenks Consultants

SOUTH TACOMA FIELD
TACOMA, WA

**DAILY MEASURED FLOW RATES AND
DAILY MEASURED RAINFALL DATA**

916055.10/P2SK065

FIGURE SW-48

However, a few recorded surface water runoff flows were characteristic of a typical stormwater runoff flow hydrograph. The surface water runoff flows that may have occurred were 11 to 14 November 1991 (249,675 gallons), and 6 to 10 December 1991 (396,340 gallons). Runoff mass loadings were also calculated for these potential runoff events using an average concentration of all five runoff (biweekly and storm) surface water samples collected at Location 2515. The total surface water runoff volume for the potential six offsite flows was 15.1 million gallons.

A new storm drain line was reportedly completed (approximately in early 1991) to connect the Tyler Street and 49th line (which conveys stormwater runoff from the landfill) to the 56th Street storm drain (Busage, P., 14 November 1990, personal communication). This new connection may cause backflow into the 72-inch storm drain and the ditch adjacent to Madison Street. Field observations made during this investigation supported this prediction. Up to 25 inches of standing water (of which some was attributable to backflow) in the 72-inch pipe was observed at the flow meter location. The flow hydrographs recorded by the flow meter were consistent with these observations. Levels would increase with little or no initial recorded velocities and as the levels decreased the velocities would greatly increase, which is typical of a backflow condition.

6.0 FINDINGS AND CONCLUSIONS

Based on the results of the Surface Water and Sediment Investigation, the following findings and conclusions are presented regarding STF surface water hydrology, and surface water (runon, onsite, and runoff) and sediment chemical characteristics.

6.1 FINDINGS

6.1.1 Hydrologic Conditions

Surface water from two upgradient sub-basins discharges onto the northwest portion of the STF site at Location 2500 (a 60-inch storm drain outfall) and Location 2501 (a 24-inch storm drain outfall). Throughout the period of this investigation, low flows were observed continuously discharging onto the site during non-storm periods through the 60-inch outfall. Low flows were observed on a sporadic basis at the 24-inch outfall. Substantial flows discharged from both outfalls during storm events.

For this investigation, the onsite surface water channel was divided into four reaches based on observed hydrologic characteristics. These reaches were identified using alphabetic designators A through D, with Reach A being the farthest upstream and Reach D being the farthest downstream. A description of these reaches is provided below:

- Reach A is a 1,400-foot long portion of the surface water channel and is located in the northwest corner of the STF site. Both storm drains discharge to this reach. Surface water was observed to be present in Reach A throughout the year of this investigation (April 1991 to April 1992).

- Reach B continues downstream (south) from Reach A for a distance of approximately 2,750 feet along the western boundary in the Airport area into the Former Swamp/Lakebed area. Reach B begins in the north as a clearly defined channel and merges in its southern portion into the south swamp remnant area consisting of marshes and bogs. During most of the investigative period, surface water was only present in appreciable quantities in the south swamp remnant area, although some "ponding" along the channel comprising the northern portion of the reach was periodically observed. Under these conditions, water throughout the reach appeared to be stagnant (i.e., did not exhibit flow conditions). During periods of heavy or extended precipitation, surface water was present throughout the reach and flow conditions were evident.
- Reach C consists of a 690-foot long segment of the channel that parallels the western STF site boundary and then turns to the east in the north end of the Former Swamp/Lakebed area. Relatively stagnant surface water was generally present throughout Reach C during this investigation, except during the dry season when water was absent from much of the reach. During periods of heavy precipitation (including those occurring in the dry season), the channel through Reach C would fill and overflow.
- Reach D consists of the southernmost 2,100 feet of the onsite channel that runs east then south (parallel with Madison Street) to the site boundary. With the exception of a small area adjoining Reach C, this reach was generally dry during non-storm periods. During this investigation, surface water was observed to flow offsite on only four occasions following extended periods of precipitation (i.e., storms of approximately 1 week in duration consisting of 2 or more inches of precipitation). The accumulation of a large volume of surface water in Reach D was necessary to produce offsite flow.

6.1.2 Inorganic Results

6.1.2.1 Surface Water Runon Quality

- Commonly detected major alkali and alkaline earth metal cations (in both the monthly surface water and stormwater runon) were calcium, magnesium, manganese, potassium, and sodium. Commonly detected metals (in both the monthly surface water and stormwater runon) were aluminum, arsenic, barium, copper, total chromium, vanadium and zinc.
- Generally, inorganic compounds were detected at higher concentrations in stormwater runon samples than in monthly surface water runon samples. An important exception to this general trend was that major cations (calcium, magnesium, potassium, and sodium) were typically detected at higher concentrations in the monthly surface water runon samples than in the stormwater runon samples.
- For both monthly and stormwater samples, most of the inorganics were detected more frequently and at higher concentration in samples collected from the 24-inch outfall (Location 2501) than in samples collected from the 60-inch outfall (Location 2500). An exception to this condition was observed in the monthly sampling results of major cations (calcium, magnesium, potassium, and sodium) and zinc (i.e., these inorganics were detected at higher concentrations in samples collected at the 60-inch outfall vs the 24-inch outfall).
- The highest concentrations for most of the inorganics were detected during the months of June through October 1991.
- Aluminum, cadmium, copper, lead, and zinc concentrations exceeded AFWQC for one or more runon samples. Aluminum,

arsenic, barium, boron, cadmium, chromium (at Location 2500 only), mercury, potassium, and sodium concentrations in runon samples exceeded the background concentrations. However, these exceedances were within reported regional and national concentration ranges.

6.1.2.2 Onsite Surface Water and Sediment Quality

- Onsite surface water concentrations for inorganics exceeded AFWQC in some instances. AFWQC were exceeded for aluminum, cadmium, copper, lead, silver, and zinc in one or more onsite samples.
- During the dry season, maximum inorganic concentrations for onsite surface water typically exceeded the runon concentrations. This finding is consistent with the expected evaporative effects that tend to concentrate inorganics in relatively stagnant surface water during drier months. In general, inorganic concentrations in onsite surface water and runon samples were similar. The exception to this general finding was that onsite surface water concentrations of copper, lead, and zinc in the wet season samples tended to be higher than those detected in wet season runon samples.
- Inorganic concentrations detected in onsite surface water were typically higher in samples collected in the southern portion of Reach A and northern portion of Reach B than in samples collected from other channel locations.
- Surface water samples collected from Reach A during the dry season contained the most elevated concentrations of inorganics (usually at Location 2528). Inorganic concentrations detected in samples collected from Reach C were generally lower than those detected in

samples from Reach A. Samples were not collected from the other reaches during the dry season because adequate quantities of surface water were not available.

- Dry weight inorganic concentrations in sediment samples exhibited similar patterns. For example, most metals (e.g., arsenic, copper, lead, and zinc) exhibited relatively low concentrations at the runon locations with a subsequent increase in the north swamp remnant. Inorganic concentrations in sediment quickly decreased from a high point in the southern portion of Reach A and generally remained fairly constant through most of Reach B. Concentrations then typically declined slowly in the southern end of Reach B and the remainder of the surface water channel, although several metals exhibited elevated concentrations in the southernmost reaches. These metals, which include arsenic, manganese, and nickel, were also detected at elevated concentrations in surface soil in the portion of the Former Swamp/Lakebed area through which Reaches C and D pass.
- Relative to other areas in the surface water channel, localized areas of high inorganic concentrations (dry weight basis) were evident in Reach B sediment based on wet season sampling results. For example, cadmium concentrations in the south swamp remnant were higher than the concentrations detected in the surface water channel to the north in Reach B. Chromium and nickel concentrations increased to 614 mg/kg and 408 mg/kg, respectively (approximately 400 feet downstream of the boundary between Reach A and Reach B) compared to 107 mg/kg and 69.3 mg/kg, respectively, reported for a sample collected farther upstream.

- When normalized to percent fine-grain material, inorganic chemical concentrations were usually elevated in Reach A compared to the remainder of the surface water channel. Normalized concentration peaks were detected in sediment samples collected at locations throughout the channel; however, the normalized pattern generally decreased in concentration from the northern to southern reaches.

6.1.2.3 Surface Water Runoff Quality

- Commonly detected inorganic compounds in surface water runoff samples (i.e., samples collected at Location 2515) were aluminum, arsenic, barium, calcium, copper, magnesium, manganese, potassium, sodium, and zinc. Boron, total chromium, mercury, and vanadium were detected less frequently in the surface water runoff samples.
- All of the inorganic chemical concentrations detected in the runoff samples were within reported concentrations occurring in U.S. surface water. However, AFWQC for aluminum, copper, and zinc were consistently exceeded in runoff samples.
- Concentrations of inorganics detected in runoff samples were typically lower than those detected in runoff samples.

6.1.3 Organic Results

Organic analyses included PAHs, VOCs, semivolatiles, and pesticides/PCBs for onsite surface water and sediment, and for surface water runoff samples collected during this investigation. Surface water runoff samples were only analyzed for PAHs.

6.1.3.1 Surface Water Runon Quality

- The most frequently detected PAHs in the surface water runon samples were fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo-(a)pyrene, indeno(1,2,3-cd)pyrene, and benzo(g,h,i)perylene. Carcinogenic PAHs were detected in both monthly and stormwater runon samples.
- Most PAHs were detected at concentrations of less than 1 $\mu\text{g/L}$. Phenanthrene, fluoranthene, pyrene, and chrysene were detected at concentrations ranging from 1 $\mu\text{g/L}$ to 3 $\mu\text{g/L}$. Concentrations detected were similar at both runon sampling locations (2500 and 2501).
- PAHs were detected more frequently and at higher concentrations in the stormwater runon samples than in the monthly runon samples.

6.1.3.2 Onsite Surface Water and Sediment Quality

- Maximum concentrations of PAHs in onsite surface water samples were similar to maximum concentrations in surface water runon.
- In sediment samples collected from Reach A during both seasons, concentrations of total and carcinogenic PAHs were 1 to 2 orders of magnitude greater than concentrations detected in samples collected from all other reaches.
- PAH concentrations (as both total PAHs and total carcinogenic PAHs) in sediment samples were approximately 2 to 4 times higher in the wet season samples than in the dry season samples.

- PAH concentration distribution along the channel axis exhibited a similar pattern in both the dry and wet season samples for both total and carcinogenic PAHs. PAHs were generally detected at elevated concentrations in sediment samples collected in the portion of Reach A that receives runoff, remained at appreciable concentrations through the southern section of Reach A and the northern section of Reach B, and then steadily declined to a relatively low level throughout the downstream remainder of the onsite channel.
- When normalized to total organic matter (TOM), concentrations of PAHs (both total and carcinogenic) in sediment collected during the wet season sampling event were higher in Reach A and the northern section of Reach B than concentrations in the remaining sections of the surface water channel.

6.1.3.3 Surface Water Runoff Quality

- PAH concentrations detected in the runoff stormwater sample were consistent with the concentrations detected in runoff samples. However, fewer PAH compounds were detected.
- The only semivolatile (non-PAH) compounds detected in the runoff surface water samples (both biweekly and stormwater runoff) were pentachlorophenol (PCP) at less than 1 $\mu\text{g/L}$ and bis(2-ethylhexyl)phthalate at less than 100 $\mu\text{g/L}$. The AFWQC was not exceeded by the PCP concentrations and WQC has not been proposed for bis(2-ethylhexyl)phthalate.

- Specific sources of PAHs, PCP, and bis(2-ethylhexyl)phthalate in the runoff surface water were not identified. Although PAHs were detected in runoff samples, analyses capable of identifying other semivolatiles were not performed on runoff samples.

6.1.4 Fecal Bacteria Results

6.1.4.1 Surface Water Quality

- Fecal bacteria concentrations in samples collected at both runoff locations generally exceeded FWQC. Fecal bacteria concentrations were higher in samples collected from the 24-inch outfall (Location 2501) than in samples collected at the 60-inch outfall (Location 2500) or at the background surface water locations.
- When compared to FWQC, the geometric mean of all of the surface water runoff fecal coliform concentrations exceeded the criterion of 200 organisms/100 mL (average of all values) and half (50 percent) of the reported concentrations exceeded the criterion of 400 organisms/100 mL (maximum concentration). However, the concentrations of fecal bacteria were within the reported range of runoff surface water fecal bacteria (coliform and streptococcus) concentrations.

6.1.5 Runon and Runoff Surface Water Volumes and Mass Loadings

- The estimated stormwater volume flowing onto the STF site at the runoff locations (2500 and 2501) was approximately 100 million gallons for 1 year (April 1991 to April 1992).

- The estimated volume of surface water discharging from the STF site at the runoff location 2515 was 14.6 million gallons for the four storm runoff events observed (30 days total). A total of 23 million gallons of runoff for the period of April 1991 through March 1992 was estimated based on flow monitoring records. However, this quantity is suspect because a majority of the recorded flow hydrographs showed characteristics typical of backflow conditions. Such conditions were observed at the 56th Street storm drain system. Additional runoff from paved areas that are located in the vicinity of the flow meter, but outside of the STF boundary, could flow into the open surface water channel and storm drain, thus contributing to the total recorded flow volume.
- In addition to the four observed storm runoff events discussed above, two recorded flow events with hydrographs characteristic of stormwater runoff flows were recorded during this investigative period. Using these additional two hydrographs, a more realistic total offsite flow volume for this investigative period was estimated to be approximately 15.1 million gallons.
- The estimated volume of surface water discharged from the STF site was substantially less than the estimated volume of surface water entering the STF site during the investigation. Therefore, the majority of surface water flowing onsite was not flowing through and off the site. Much of the surface water runoff is dissipated onsite due to evaporation, transpiration, and infiltration through the soil to recharge the upper aquifer at the site.
- The estimated mass loadings of inorganics in the surface water runoff were greater by several orders of magnitude than potential mass loadings of inorganics in the surface water runoff. Aluminum, arsenic, barium, total chromium, iron, manganese, and nickel runoff mass loadings were between 5 to 15 times greater than the runoff mass loadings. Runoff mass loadings

for boron, copper, lead, magnesium, potassium, vanadium, and zinc were up to 35 times greater than the runoff mass loadings. Runon mass loadings for sodium and cobalt were 160 and 500 times greater than runoff mass loadings, respectively.

6.2 CONCLUSIONS

The following conclusions have been developed based on the findings of this investigation.

6.2.1 Background Surface Water

- Background surface water quality shows effects of urban surface water runoff contamination due to anthropogenic sources. Eleven inorganic chemicals [metals (i.e., aluminum, barium, copper, iron, lead, and zinc) and major alkali and alkaline earth metal cations (calcium, magnesium, manganese, potassium, and sodium)] were detected consistently in background surface water samples. Three metals (aluminum, copper, and zinc) exceeded AFWQC at least once in the background samples. PAHs were detected at background locations with higher concentrations detected during the dry season. Two VOCs (acetone and chloroform) were detected during the dry season background sampling event. One non-PAH semivolatile compound [bis(2-ethylhexyl)phthalate] was detected. No PCB or pesticides were detected in any of the background samples.

6.2.2 Surface Water Runon

- Surface water from two upgradient sub-basins discharges onto the northwest portion of the STF site. Other appreciable surface water runon from offsite into the onsite surface water channel was not directly observed during this investigation. Runon flows from the two onsite storm drain outfalls appears to constitute the major source of onsite surface water. The source(s) of the surface water entering Reach C was not observed during this investigation. Possible sources of water entering this reach are the flow of upstream surface water down the channel, sheet runoff from the offsite hillside on the western boundary of the channel, or groundwater discharge into the channel.
- The surface water runon discharging onto the site through the two storm drain outfalls exhibited degraded quality characteristic of urban runoff. Concentrations of inorganics, PAHs, and fecal bacteria detected in the runon samples were generally equal to or higher than those detected in onsite surface water, and appear to be significantly elevated as a result of offsite human activities.
- Major cation concentrations detected in runon samples collected during storm events were significantly less than those detected in monthly (low flow) samples. This finding is consistent with the expected chemical composition of stormwater runoff that has had a short contact time with earth materials as compared to non-storm event flows that may contain groundwater seepage or other waters with longer earth material contact times. Conversely, concentrations of inorganics and PAHs were generally higher in stormwater runoff samples than in monthly samples suggesting that these contaminants are mobilized and transported from the surrounding urban environment during storm events following their surface accumulation during drier periods. Sources of PAHs in the runon surface

water are ubiquitous in urban environments. Some of these sources include petroleum products such as gasoline, tars and heavy oils, and products of combustion processes such as those produced by internal combustion engines.

6.2.3 Onsite Surface Water and Sediment

- The onsite surface water system is relatively complex with respect to the potential geochemical processes that affect surface water quality. Possible sources of metals and PAHs potentially affecting onsite surface water quality may be runoff and contaminated sediment that have deposited onsite. Therefore, principle factors affecting onsite surface water quality are 1) the chemical quality of runoff, and 2) appreciable changes in the onsite surface water environment that will influence the mobility and transport of previously deposited contaminants through processes such as dissolution and/or resuspension.
- Sediment containing metals and PAHs may serve as a source to onsite surface water. The highest concentrations of metals and PAHs appear to be present in the upstream reaches (Reaches A and B), with the highest concentrations of PAHs being present near the storm drain outfalls.
- Based on the runoff conditions observed during storm events and site topography, overland transport of surface soil from other areas of the STF site does not appear to be a significant mechanism for migration of metals and PAHs into the surface water channel. Accordingly, the possible sources of metals and PAHs in onsite surface water sediment may be 1) historical deposition of metal-bearing materials into the channel by either direct discharge or human activities resulting in enhancing erosion of such

materials, 2) deposition of contaminants contained in runoff of degraded quality, or 3) deposition of airborne contaminants.

- Evaluation of the graphs depicting metals and PAH concentration distributions along the onsite surface water channel (showing dry weight and normalized concentrations) support the conclusion that contamination of onsite sediment is at least partially attributable to deposition of contaminants carried onsite by runoff discharged from the storm drain outfalls. This conclusion is supported by relatively high concentrations detected in sediment in Reaches A and B. In addition, the observed series of "peak" concentration points along the channel, the amplitude of which progressively decrease with distance downstream from the outfalls, are consistent with resuspension and redeposition phenomena as adsorbed metals and PAHs are progressively transported downstream by years of storm events. Such a concentration distribution is consistent with the expected patterns of initial introduction of contaminants into the onsite surface water channel by stormwater drain discharges followed by contaminant attenuation as it moves through wider reaches and vegetated areas further downstream.
- Higher metal and PAH concentrations were detected in onsite surface water samples collected during the dry season than in samples collected during the wet season. This finding is consistent with the concentrations of contaminants observed in stagnant surface water bodies subjected to net evaporative conditions.
- Metals and PAHs in runoff are probably the source for much of the loading to the surface water channel in Reach A. The lower concentrations detected in surface water in the north swamp remnant are typical of a relative quiescent pool where suspended solids have an opportunity to settle out of solution. Chemicals that were generally detected at higher

concentrations at the boundary of Reaches A and B may be attributable to an unidentified localized source. A coated metal culvert was observed in the vicinity of the surface water channel. Surface water metal concentrations were generally relatively uniform in Reach C. For some chemicals (e.g., arsenic, barium, calcium), concentrations increased slightly at the southern end of Reach C. It appears that the road at this location may act as a hydraulic barrier to create a pool for suspended metals to settle.

6.2.4 Surface Water Runoff

- Surface water was only observed flowing from the site during periods of heavy and/or prolonged precipitation. Based on these observations and the water balance calculations made as part of this investigation, it is reasonable to conclude that the onsite surface water channel serves as a recharge zone for the shallow aquifer in the area.
- The quality of runoff from the site was consistent with or better than runoff quality throughout the investigation, suggesting that the overall function of the onsite surface water channel is one of settling, absorbing, and otherwise retaining much of the contaminant load discharged to it from offsite, upstream sources.
- Mass loading estimations (made as part of the analysis of data gathered during this investigation) suggest that a significant quantity of the metals and PAHs discharged from offsite sources into the onsite surface water channel are retained onsite.

7.0 REFERENCES

Agency for Toxic Substances and Disease Registry. 1987a. Toxicological Profile for Benz(a)anthracene. Draft. Prepared by ICF-Clement Under Contract No. 68-02-4235. Prepared for U.S. Public Health Services, ATSDR in collaboration with U.S. EPA. Published by Oak Ridge National Laboratory, Oak Ridge, TN.

Agency for Toxic Substances and Disease Registry. 1987b. Toxicological Profile for Benzene. Draft. Prepared by Oak Ridge National Laboratory Under Contract No. DW89932147-01-3. Prepared for U.S. Public Health Services, ATSDR in collaboration with U.S. EPA. Published by Oak Ridge National Laboratory, Oak Ridge, TN.

Agency for Toxic Substances and Disease Registry. 1987c. Toxicological Profile for Benzo(a)pyrene. Draft. Prepared by ICF-Clement Under Contract No. 68-02-4235. Prepared for U.S. Public Health Services, ATSDR in collaboration with U.S. EPA. Published by Oak Ridge National Laboratory, Oak Ridge, TN.

Agency for Toxic Substances and Disease Registry. 1987d. Toxicological Profile for Benzo(b)fluoranthene. Draft. Prepared by ICF-Clement Under Contract No. 68-02-4235. Prepared for U.S. Public Health Services, ATSDR in collaboration with U.S. EPA. Published by Oak Ridge National Laboratory, Oak Ridge, TN.

Agency for Toxic Substances and Disease Registry. 1987e. Toxicological Profile for Beryllium. Draft. Prepared by Syracuse Research Corporation Under Contract No. 68-03-3228. Prepared for U.S. Public Health Services, ATSDR in collaboration with U.S. EPA. Published by Oak Ridge National Laboratory, Oak Ridge, TN.

Agency for Toxic Substances and Disease Registry. 1987f. Toxicological Profile for Cadmium. Draft. Prepared by Life Systems, Inc. Under Contract No. 68-02-4228. Prepared for U.S. Public Health Services, ATSDR in collaboration with U.S. EPA. Published by Oak Ridge National Laboratory, Oak Ridge, TN.

Agency for Toxic Substances and Disease Registry. 1987g. Toxicological Profile for Chromium. Draft. Prepared by Syracuse Research Corporation Under Contract No. 68-03-3228. Prepared for U.S. Public Health Services, ATSDR in collaboration with U.S. EPA. Published by Oak Ridge National Laboratory, Oak Ridge, TN.

Agency for Toxic Substances and Disease Registry. 1987h. Toxicological Profile for Chrysene. Draft. Prepared by ICF-Clement Under Contract No. 68-02-4235. Prepared for U.S. Public Health Services, ATSDR in collaboration with U.S. EPA. Published by Oak Ridge National Laboratory, Oak Ridge, TN.

Agency for Toxic Substances and Disease Registry. 1987i. Toxicological Profile for Dibenz(a,h)anthracene. Draft. Prepared by ICF-Clement Under Contract No. 68-02-4235. Prepared for U.S. Public Health Services, ATSDR in collaboration with U.S. EPA. Published by Oak Ridge National Laboratory, Oak Ridge, TN.

Agency for Toxic Substances and Disease Registry. 1987j. Toxicological Profile for Methylene Chloride. Draft. Prepared by Life Systems, Inc. Under Contract No. 68-02-4228. Prepared for U.S. Public Health Services, ATSDR in collaboration with U.S. EPA. Published by Oak Ridge National Laboratory, Oak Ridge, TN.

Agency for Toxic Substances and Disease Registry. 1987k. Toxicological Profile for Nickel. Draft. Prepared by Syracuse Research Corporation Under Contract No. 68-03-3228. Prepared for U.S. Public Health Services, ATSDR in collaboration with U.S. EPA. Published by Oak Ridge National Laboratory, Oak Ridge, TN.

Agency for Toxic Substances and Disease Registry. 1987l. Toxicological Profile for Selected PCBs (Aroclor-1260, -1254, -1248, -1242, -1232, -1221, and -1016). Draft. Prepared by Syracuse Research Corporation Under Contract No. 68-03-3228. Prepared for U.S. Public Health Services, ATSDR in collaboration with U.S. EPA. Published by Oak Ridge National Laboratory, Oak Ridge, TN.

Agency for Toxic Substances and Disease Registry. 1988a. Toxicological Profile for Cyanide. Draft. Prepared by Technical Resources, Inc. Under Contract No. 68-03-3268. Revised by Syracuse Research Corporation Under Contract No. 68-03-3521. Prepared for U.S. Public Health Services, ATSDR in collaboration with U.S. EPA. Published by Oak Ridge National Laboratory, Oak Ridge, TN.

Agency for Toxic Substances and Disease Registry. 1988b. Toxicological Profile for Lead. Draft. Prepared by Technical Resources, Inc. Under Contract No. 68-03-3268. Revised by Syracuse Research Corporation Under Contract No. 68-03-3521. Prepared for U.S. Public Health Services, ATSDR in collaboration with U.S. EPA. Published by Oak Ridge National Laboratory, Oak Ridge, TN.

Agency for Toxic Substances and Disease Registry. 1988c. Toxicological Profile for Mercury. Draft. Prepared by Clement Associates Under Contract No. 205-88-0608. Prepared for U.S. Public Health Services, ATSDR in collaboration with U.S. EPA. U.S. Government Printing Office, Washington, DC.

Agency for Toxic Substances and Disease Registry. 1988d. Toxicological Profile for Phenol. Draft. Prepared by Clement Associates Under Contract No. 205-88-0608. Prepared for U.S. Public Health Services, ATSDR in collaboration with U.S. EPA. U.S. Government Printing Office, Washington, DC.

Agency for Toxic Substances and Disease Registry. 1988e. Toxicological Profile for Selenium. Draft. Prepared by Clement Associates Under Contract No. 205-88-0608. Prepared for U.S. Public Health Services, ATSDR in collaboration with U.S. EPA. U.S. Government Printing Office, Washington, DC.

Agency for Toxic Substances and Disease Registry. 1988f. Toxicological Profile for Toluene. Draft. Prepared by Clement Associates Under Contract No. 205-88-0608. Prepared for U.S. Public Health Services, ATSDR in collaboration with U.S. EPA. U.S. Government Printing Office, Washington, DC.

Agency for Toxic Substances and Disease Registry. 1988g. Toxicological Profile for Vanadium. Draft. Prepared by Clement Associates Under Contract No. 205-88-0608. Prepared for U.S. Public Health Services, ATSDR, Atlanta, GA. U.S. Government Printing Office, Washington, DC.

Agency for Toxic Substances and Disease Registry. 1988h. Toxicological Profile for Zinc. Draft. Prepared by Clement Associates Under Contract No. 205-88-0608. Prepared for U.S. Public Health Services, ATSDR in collaboration with U.S. EPA. U.S. Government Printing Office, Washington, DC.

Agency for Toxic Substances and Disease Registry. 1989a. Toxicological Profile for Chloroform. Draft. Prepared by Syracuse Research Corporation Under Contract No. 68-C8-0004. Prepared for U.S. Public Health Services, ATSDR in collaboration with U.S. EPA. Published by Oak Ridge National Laboratory, Oak Ridge, TN.

Agency for Toxic Substances and Disease Registry. 1989b. Toxicological Profile for Copper. Draft. Prepared by Syracuse Research Corporation Under Subcontract No. ATSDR-88-0608-02 for U.S. Public Health Services, ATSDR, Atlanta, GA. U.S. Government Printing Office, Washington, DC.

Agency for Toxic Substances and Disease Registry. 1990a. Toxicological Profile for Antimony. Draft. Prepared by Syracuse Research Corporation Under Subcontract (Contract No. 205-88-0608) to Clement Associates, Inc. Prepared for U.S. Public Health Services, ATSDR, Atlanta, GA. U.S. Government Printing Office, Washington, DC.

Agency for Toxic Substances and Disease Registry. 1990b. Toxicological Profile for Barium. Draft. Prepared by Clement Associates, Inc. Under Contract No. 205-88-0608. Prepared for U.S. Public Health Services, ATSDR, Atlanta, GA. U.S. Government Printing Office, Washington, DC.

Agency for Toxic Substances and Disease Registry. 1990c. Toxicological Profile for 2,3-Benzofuran. Draft. Prepared by Life Systems, Inc. Under Subcontract (Contract No. 205-88-0608) to Clement Associates, Inc. Prepared for U.S. Public Health Services, ATSDR, Atlanta, GA. U.S. Government Printing Office, Washington, DC.

Agency for Toxic Substances and Disease Registry. 1990d. Toxicological Profile for Boron. Draft. Prepared by Life Systems, Inc. Under Subcontract (Contract No. 205-88-0608) to Clement Associates, Inc. Prepared for U.S. Public Health Services, ATSDR, Atlanta, GA. U.S. Government Printing Office, Washington, DC.

Agency for Toxic Substances and Disease Registry. 1990e. Toxicological Profile for Manganese. Draft. Prepared by Life Systems, Inc. Under Subcontract (Contract No. 205-88-0608) to Clement Associates, Inc. Prepared for U.S. Public Health Services, ATSDR, Atlanta, GA. U.S. Government Printing Office, Washington, DC.

Agency for Toxic Substances and Disease Registry. 1990f. Toxicological Profile for Nitrophenols: 2-Nitrophenol and 4-Nitrophenol. Draft. Prepared by Syracuse Research Corporation Under Subcontract (Contract No. 205-88-0608) to Clement Associates, Inc. Prepared for U.S. Public Health Services, ATSDR, Atlanta, GA. U.S. Government Printing Office, Washington, DC.

Agency for Toxic Substances and Disease Registry. 1990g. Toxicological Profile for Silver. Draft. Prepared by Clement Associates, Inc. Under Contract No. 205-88-0608. Prepared for U.S. Public Health Services, ATSDR, Atlanta, GA. U.S. Government Printing Office, Washington, DC.

Agency for Toxic Substances and Disease Registry. 1990h. Toxicological Profile for Thallium. Draft. Prepared by Life Systems, Inc. Under Subcontract (Contract No. 205-88-0608) to Clement Associates, Inc. Prepared for U.S. Public Health Services, ATSDR, Atlanta, GA. U.S. Government Printing Office, Washington, DC.

Agency for Toxic Substances and Disease Registry. 1990i. Toxicological Profile for Vanadium. Draft. Prepared by Clement Associates, Inc. Under Contract No. 205-88-0608. Prepared for U.S. Public Health Services, ATSDR, Atlanta, GA. U.S. Government Printing Office, Washington, DC.

American Public Health Association. 1989. Standard Methods for the Examination of Water and Wastewater. 17th Edition. Prepared and published jointly by American Public Health Association, American Water Works Association, and Water Pollution Control Board. Publication Office, APHA, Washington, DC.

Bennett, D. 3 January 1992. Personal Communication (telephone conversation with Ms. Glynda Steiner, Kennedy/Jenks Consultants regarding CERCLIS site history for South Tacoma Field). David Bennett, U.S. Environmental Protection Agency, Region 10, Seattle, WA.

Black & Veatch. 1983. Preliminary Site Investigation, South Tacoma Swamp, Tacoma, Washington. Prepared for U.S. Environmental Protection Agency, Cincinnati, OH. Black & Veatch, Engineers-Architects, Tacoma, WA. 17 pp. plus appendices.

Black & Veatch. 1987. Remedial Investigation Report, Tacoma Landfill, Tacoma, Washington. Volume 1 (Volumes 2 and 3 Appendices). Prepared for the City of Tacoma, Washington. Black & Veatch, Engineers-Architects, Tacoma, WA.

Black & Veatch. 1990. Draft Predesign Study Report, Tacoma Landfill Remedial Design, Tacoma, Washington. Volumes 1 and 2. Prepared for the City of Tacoma, Refuse Utility Division, Tacoma, Washington. Black & Veatch, Waste Science and Technology Corporation, Tacoma, WA and Pacific Groundwater Group, Seattle, WA.

Brown and Caldwell. 1985. Clover/Chambers Creek Geohydrologic Study for Tacoma-Pierce County Health Department. Final Report. Brown and Caldwell, Seattle, WA with subconsultants Sweet, Edwards & Associates, and Robinson & Noble, Inc., Tacoma, WA.

Busage, P. 14 November 1990. Personal Communication (telephone conversation with Ms. Dana B. De Leon, Kennedy/Jenks Consultants). Mr. Paul Busage, Tacoma Public Utilities, Tacoma, WA.

Dragun, J. 1988. The Soil Chemistry of Hazardous Materials. Hazardous Materials Control Research Institute, Silver Springs, MD.

Entranco Engineers. 1989. Snake Lake Restoration. A Phase 1 - Diagnostic and Restoration Feasibility Study. Prepared for Metropolitan Park District of Tacoma and Washington Department of Ecology under Referendum 39 Lake Restoration Program. Entranco Engineers, Inc., Kirkland, WA. 76 pp. plus appendices.

Fairchild Aerial Surveys. 1950. City of Tacoma, Washington, Metropolitan Topographic Survey, Sections 1-20-3, 6-20-3, 7-20-3, 12-20-2, and 13-20-2. Scale 1:24,000. Prepared under the direction of the Commissioner of Public Works of Tacoma, Washington. Fairchild Aerial Surveys, Inc.

Hem, J.D. 1989. Study and Interpretation of the Chemical Characteristics of Natural Water. 3rd Edition. U.S. Geological Survey Water-Supply Paper 2254. 263 pp.

Howard, P.H. 1989. Handbook of Environmental Fate and Exposure Data for Organic Chemicals. Volume I, Large Production and Priority Pollutants. Lewis Publishers, Inc., Chelsea, MI. 574 pp.

Howard, P.H. 1990. Handbook of Environmental Fate and Exposure Data for Organic Chemicals. Volume II, Solvents. Lewis Publishers, Inc., Chelsea, MI. 546 pp.

Howard, P.H. 1991. Handbook of Environmental Fate and Exposure Data for Organic Chemicals. Volume III, Pesticides. Lewis Publishers, Inc., Chelsea, MI. 684 pp.

ICF. 1990a. Draft Site Background Summary for the South Tacoma Field Superfund Site. Revision 0, April 1990. EPA Work Assignment 59-04-OL10. Prepared for U.S. EPA, Region 10, Seattle, WA. ICF Technology, Inc., Bellevue, WA.

ICF. 1990b. Final Work Plan, Remedial Investigation and Feasibility Study, South Tacoma Field, Tacoma, Washington. Revision 1, September 1990. EPA Work Assignment 59-04-OL10. Prepared for U.S. EPA, Region 10, Seattle, WA. ICF Technology, Inc., Bellevue, WA.

Kennedy/Jenks/Chilton. 1987. Remedial Investigation/Risk Assessment/Feasibility Study, Former Brass Foundry Area, South Tacoma Swamp, Volume 1. Draft. Prepared for Tacoma Industrial Properties (TIP) Management, Inc., Tacoma, WA. Kennedy/Jenks/Chilton, Federal Way, WA.

Kennedy/Jenks/Chilton. 1988. Site Investigation/Surface Waste Removal, Former Iron Foundry Area, South Tacoma Swamp. Prepared for Tacoma Industrial Properties (TIP) Management, Inc., Tacoma, WA. Kennedy/Jenks/Chilton, Federal Way, WA.

Kennedy/Jenks/Chilton. 1990. After Action Report, Former Griffin Wheel Brass Foundry, Tacoma, Washington. Prepared for Amsted Industries, Inc., Chicago, IL. Kennedy/Jenks/Chilton, Federal Way, WA.

Kennedy/Jenks/Chilton. 1991a. South Tacoma Field Superfund Site, Document and Data Management Plan. Prepared for South Tacoma Field Site Group. Final Report dated 25 January 1991. Kennedy/Jenks/Chilton, Federal Way, WA.

Kennedy/Jenks/Chilton. 1991b. South Tacoma Field Superfund Site, Field Sampling and Analysis Plan. Prepared for South Tacoma Field Site Group. Revisions issued 1 March 1991 and 28 August 1991, includes STF FSAP Addendum 1, Supplemental Soil Characterization, Revision 1, 11 June 1991. Kennedy/Jenks/Chilton, Federal Way, WA.

Kennedy/Jenks/Chilton. 1991c. South Tacoma Field Superfund Site, Quality Assurance Project Plan (3 volumes). Prepared for South Tacoma Field Site Group. Revisions to Volume 1 issued 1 and 20 March 1991 and 5 September 1991. Final Revisions to Volume 2 (Appendix E - Pacific Environmental Laboratory QAPP) and Volume 3 (Appendix F - ATI-Renton and San Diego Laboratories QAPPs) issued 20 March 1991. Kennedy/Jenks/Chilton, Federal Way, WA.

Kennedy/Jenks/Chilton. 1991d. South Tacoma Field Superfund Site, Site Safety and Health Plan. Prepared for South Tacoma Field Site Group. Final Revisions Issued 1 February 1991. Kennedy/Jenks/Chilton, Federal Way, WA.

Kennedy/Jenks/Chilton. 1991e. South Tacoma Field Superfund Site, Wetlands Investigation Field Sampling and Analysis Plan Amendment. Prepared for South Tacoma Field Site Group. Final Report dated 19 March 1991. Kennedy/Jenks/Chilton, Federal Way, WA.

Kennedy/Jenks Consultants. 1991a. South Tacoma Field Superfund Site, Phase I Soil Investigation Data Appendix. 27 November 1991. Kennedy/Jenks Consultants, Federal Way, WA.

Kennedy/Jenks Consultants. 1991b. South Tacoma Field Superfund Site, Phase I Groundwater Investigation Data Appendix. 5 December 1991. Kennedy/Jenks Consultants, Federal Way, WA.

Kennedy/Jenks Consultants. 1992a. South Tacoma Field Superfund Site, Phase I Soil Investigation Report and Reference Appendix. Prepared for South Tacoma Field Site Group. Draft Report dated 6 January 1992. Kennedy/Jenks Consultants, Federal Way, WA.

Kennedy/Jenks Consultants. 1992b. South Tacoma Field Superfund Site, Phase I Groundwater Investigation Report. Prepared for South Tacoma Field Site Group. Draft Report dated 27 January 1992. Kennedy/Jenks Consultants, Federal Way, WA.

Kennedy/Jenks Consultants. 1992c. South Tacoma Field Superfund Site, Surface Water and Sediment Investigation Data Appendix. Prepared for South Tacoma Field Site Group. 20 April 1992. Kennedy/Jenks Consultants, Federal Way, WA.

Kennedy/Jenks Consultants and LSA Associates. 1991. South Tacoma Field Superfund Site, Wetland Delineation and Endangered Plant Species Survey. Prepared by LSA Associates, Inc., Pt. Richmond, CA in association with Kennedy/Jenks Consultants for South Tacoma Field Site Group. 29 October 1991. Kennedy/Jenks Consultants, Federal Way, WA. 12 pp. plus 3 appendices.

Lum, W.E., and G.L. Turney. 1985. A Preliminary Evaluation of Hydrology and Water Quality Near the Tacoma Landfill, Pierce County, Washington. U.S. Geological Survey, Water-Resources Investigations Report 84-4351. Prepared in cooperation with the State of Washington Department of Ecology. 35 pp.

Noble, J.B. 1990. Proposed Revision of Nomenclature for the Pleistocene Stratigraphy of Coastal Pierce County, Washington. Washington State Department of Natural Resources, Division of Geology and Earth Resources, Open File Report 90-4. 54 pp.

ReTec. 1987. Phase 1 Report, Remedial Investigation of the South Tacoma Swamp Superfund Site. C86027-290. May 1987. Prepared for Burlington Northern Railroad, Seattle, WA. Remediation Technologies, Inc., Kent, WA. 39 pp. plus 7 appendices.

Sittig, M. 1985. Handbook of Toxic and Hazardous Chemicals and Carcinogens. 2nd Edition. Noyes Publications, Park Ridge, NJ. 950 pp.

Tacoma, City of. 1991. Zoning Map of City of Tacoma, Washington. Tacoma Geographic Base System, plot date 7 August 1991. Scale 1:2,000. Planning and Development Services Department, Growth Management Services Division, Public Works Department, and Building and Land Use Services Division. Produced by Tacoma Information Systems.

Thorson, R.M. 1980. Ice-Sheet Glaciation of the Puget Lowland, Washington, during the Vashon Stade (Late Pleistocene). Quaternary Research 13:303-321.

Turney, G.L. 1986. Quality of Ground Water in the Puget Sound Region, Washington, 1981. U.S. Geological Survey Water-Resources Investigations Report 84-4258.

U.S. Department of Agriculture. 1979. Soil Survey of Pierce County Area, Washington. USDA, Soil Conservation Service (Puyallup, WA) in cooperation with the Washington Agricultural Experiment Station, Pullman, WA.

U.S. Environmental Protection Agency. 1983. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020. U.S. EPA, Office of Research and Development, Environmental Monitoring and Support Laboratory, Cincinnati, OH.

U.S. Environmental Protection Agency. 1984. Field Investigation Feasibility Study, South Tacoma Channel, Washington (South Tacoma Public Well 12A). Final Draft Report. EPA 81.OL31. EPA Contract No. 68-01-6692. Prepared by CH2M Hill and Ecology and Environment, Remedial Planning/Field Investigation Team (REM/FIT), Zone II. U.S. EPA, Hazardous Site Control Division, Washington, DC.

U.S. Environmental Protection Agency. 1986a. Health Effects Assessment for Methylene Chloride. EPA/540/1-86/028. Prepared by Office of Research and Development, Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Cincinnati, OH. U.S. EPA, Office of emergency and Remedial Response, Washington, DC. 48 pp.

U.S. Environmental Protection Agency. 1986b. Test Methods for Evaluating Solid Waste. Volumes 1A, 1B, and 1C: Laboratory Manual Physical/Chemical Methods. SW-846, 3rd edition. U.S. EPA, Office of Solid Waste and Emergency Response, Washington, DC.

U.S. Environmental Protection Agency. 1986c. Quality Criteria for Water, 1986. EPA 440/5-86-001. U.S. EPA, Office of Water Regulations and Standards, Washington, DC.

U.S. Environmental Protection Agency. 1987a. Health and Environmental Effects Profile for Anthracene. Draft. ECAO-CIN-P230. Prepared for Office of Solid Waste and Emergency Response by Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Cincinnati, OH. 83 pp.

U.S. Environmental Protection Agency. 1987b. Update to the Health Assessment Document and Addendum for Dichloromethane (Methylene Chloride): Pharmacokinetics, Mechanism of Action, and Epidemiology. Review Draft. EPA/600/8-87/030A. Prepared by Office of Research and Development, Office of Health and Environmental Assessment, Washington, DC. 119 pp.

U.S. Environmental Protection Agency. 1988a. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Interim Final. EPA/540/G-89/004. OSWER Directive 9355.3-01. U.S. EPA, Office of Emergency and Remedial Response, Washington, DC.

U.S. Environmental Protection Agency. 1988b. Contract Laboratory Program, Statement of Work for Organics Analysis, Multi-Media, Multi-Concentration. SOW No. 2/88, including rev/ 9/88 and 4/89.

U.S. Environmental Protection Agency. 1988c. Laboratory Data Validation Functional Guidelines for Evaluating Inorganics Analyses. Draft, 1 July 1988. Prepared for the Hazardous Site Evaluation Division. U.S. EPA, Data Review Work Group. 19 pp.

U.S. Environmental Protection Agency. 1988d. Laboratory Data Validation Functional Guidelines for Evaluating Organics Analyses. Draft, 1 February 1988. Prepared for the Hazardous Site Evaluation Division. U.S. EPA, Data Review Work Group. 43 pp.

U.S. Environmental Protection Agency. 1988e. Memorandum regarding revised data validation guidelines issued by Carla Dempsy, EPA Analytical Operations Branch.

U.S. Environmental Protection Agency. 1990a. Contract Laboratory Program, Statement of Work for Organics Analysis, Multi-Media, Multi-Concentration. Document No. OLM01.0.

U.S. Environmental Protection Agency. 1990b. Contract Laboratory Program, Statement of Work for Inorganics Analysis, Multi-Media, Multi-Concentration. Document No. ILM01.0.

U.S. Geological Survey. 1978. Isostatic Effects of the Last Glaciation in the Puget Lowland, Washington. U.S. Geological Survey Open-File Report 75-344.

Walters, K.L., and G.E. Kimmel. 1968. Ground-Water Occurrence and Stratigraphy of Unconsolidated Deposits, Central Pierce County, Washington. Washington Department of Water Resources Water Supply Bulletin 22.